Multi Process Output From Common Data Base

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ABSTRACT

Electronic page make-up systems working from a single digital image data base offer the possibility to output films for many printing conditions. Look up tables may be used to manipulate the composite images.

These look-up tables accommodate the same requirements as needed in original color separation. The variables of ink on paper for any process must first be standardized before conversion tables can be developed. **SWOP** and **G.T.A. Group V** standards form a starting point from which experimental data has been derived.

This paper describes an ongoing effort by the Scitex Corporation to quantify process variables and develop conversion techniques for its users.

OBJECTIVES

Two different objectives may be met through the ability to work from a single image data base.

A. Produce films for Offset Litho, Gravure, or other process printing from the same scanned data.

B. Produce halftone screened film to allow accurate pre-press proving for Gravure.

Scitex users today may be classified into two distinct catagories for which either objective A or B is applicable.

1. Photoengravers (Trade houses) whose primary business is supplying Offset films but who also supply continuous tone or gravure halftone films to Gravure Printers. The majority of national ads printed in Gravure publications use films supplied by trade houses.

2. Gravure printers who generally do their own pre-press for editorial matter and some local advertising in publications.

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By and large, the trade house is more familiar with and has an easier time scanning and correcting for Offset than Gravure. Some of our trade house users have separate Gravure preparation facilities. However, scans are still made on scanners doing mostly Offset work. Other trade houses have little or no experience in Gravure but would like to penetrate the growing Gravure market. With a workable conversion program, the trade house can continue to work in the familiar Offset mode even for Gravure customers. Scanning, correcting, image assembly, pre-press proving and even press proving can all be Offset. Once pre-press or press proofs are approved, a new set of films can be generated on the laser plotter in continuous tone or gravure halftone mode. Just before exposure, the composite page files are processed through the appropriate look-up tables. Of course, this can only work if sufficient calibration and testing has been done to assure compatibility of results from offset proofs and gravure press runs.

Gravure printers generally have considerable experience scanning and correcting in continuous tone. However, they are still plagued by costly proving methods. Recent advances in pre-press proving by material manufacturers are improving the situation. The trend towards screened gravure films is also easing the making of accurate pre-press proofs. However, there are still problems in matching toners or dyes and their behavior in overprints throughout the tone range.

Using an image data base conversion program, the Gravure printer can conceivably use any pre-press proving method of his choice. The dyes or toners, and general procedure would be unchanged from established Offset litho set up. A separate set of films would be exposed on the laser plotter just for proving.

In either case, a "perfect" match can never be expected. Nothing short of using the identical paper/ink/press combination can approach this ideal. Whatever proving method is used will require empirical data and industry acceptance of how close is good enough.

For either the trade house or the Gravure printer, the general procedure would be:

a) Scan and process images on the Scitex system for the most familiar process.

b) Convert the composite image data base for the second process or for proving if necessary.

Conversion Factors

In the course of making color separation films, masking is performed to modulate RGB signals. This is necessary to accommodate the limitations of particular ink/paper/press combinations. Four major requirements are affected by this process.

A. Tone Reproduction
B. Gray Balance
C. Color Correction
D. Under Color Removal and the black printer.

The screening process in halftone separations also affects or controls some of these factors, especially tone reproduction (within the compressed tone range) and gray balance.

There is one major difference between color separation for Gravure and Offset. Offset plates are a virtual non-variable in color reproduction. There is no difference in exposure and development procedures among the four color plates.

Cylinder engraving on the other hand, whether by chemical or mechanical means, may vary among colors. Like the screening process in Offset litho separtions, tone reproduction (within the compressed tone range) and gray balance are affected.

In other words, all the requirements for good color separation are built into Offset films while in Gravure, the separation process is not complete until cylinders are engraved. This fundamental difference adds complexity to development of a conversion program. Besides the need for standards in printing, the cylinder engraving process must be standardized so that control of all separation requirements can be built into the film.

G.T.A. (Gravure Technical Association) standards have been established which equate continuous tone densities on separation films to reflection densities on the printed sheet. If these standards are strictly adhered to, the cylinder engraving process need not be of concern in developing a conversion program. It has been the author°s experience while accumulating empirical data for this project, that engravers and printers have some difficulty maintaining these standards. This is most evident in matching gray balance requirements (equal densities on film) in gravure proving.

Preliminary Consideration

Before discussing test results and procedures a comment should be made concerning the nature of corrections for all four requirements mentioned. The original data base in the color separation process is the transparency or reflective art. The data captured on film separations or in digital form in an electronic page make-up system is a compressed and biased sampling of the original. Picture data undergoes far more alteration in original scanning than in converting from one process to another. Basically, the four color separation requirements are similar from one print process to another. Were this not so, there could be no substitute for making different separations for each process. The data extracted from the copy in such a case would need to be different. It also follows suit that poorly made separations will reproduce poorly by any print process.

A. Tone Reproduction

The density range of a color transparency is normally greater than the reflection density range of ink on paper. To correct for this problem, tone compression is performed during scanning. The tone range is not compressed in a linear manner but rather according to a curve emphasizing midtone contrast at the expense of highlight and shadow contrast (true for normal key copy only). Tone reproduction is usually represented by a graph plotting original density on the transparency against reflective density on the press sheet (see Fig. A1)

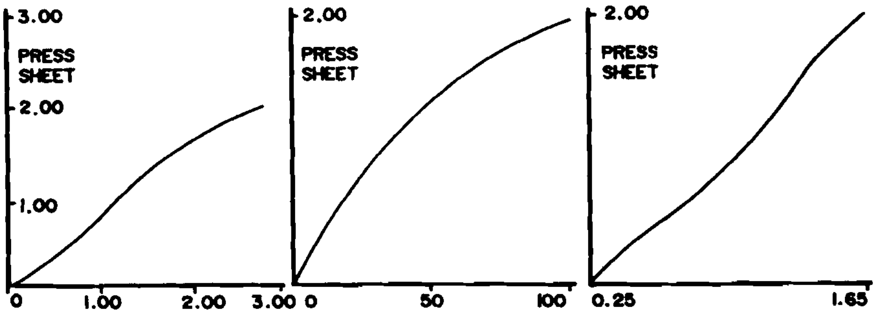

FIG A1 FIG A2 FIG A3

A quantitative objective would be to maintain this tone reproduction curve for any print process used. To do this, empirical data must be derived equating reflection densities on the printed sheet to either dot area on halftone films or transmission density on continuous tone films (Figures A2 and A3). Film to press characteristic curves for any two conditions can then be combined to develop a film to film correction curve. A Jones diagram such as shown in figure A4 demonstrates this process.

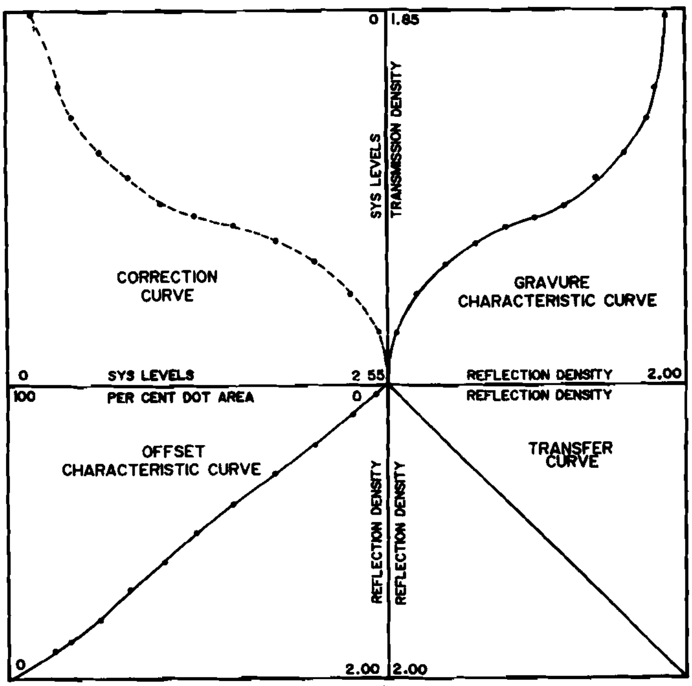

Fig. A4

Experimental data for developing a correction curve has been derived by the following means:

For the Offset litho condition, a Cromalin proof (using SWOP toners) of a special test image was used. Transmission readings were taken from the cyan separation along an equal dot area step wedge. Reflection readings from equivalent locations on the four color overprints were plotted against the cyan transmission readings to develop the Offset litho characteristic curve. Reflection densities were zeroed to the substraight.

For the Gravure condition, the calibration page (25) of the G.T.A. standards book for Group V inks was used. Transmission densities of the 18-step wedge were recorded as printed in the book. Reflection densities were measured from the four color overprint using the same reflection densitometer as used for the Offset condition. The densitometer was again zeroed to the paper.

Characteristic curves were plotted on linear graph paper as shown in figures A5 and A6.

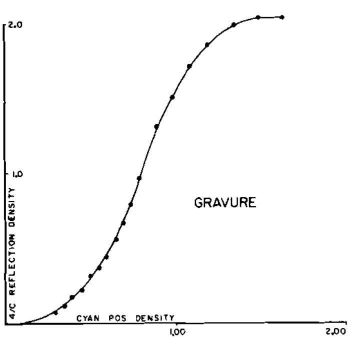

FIG A5

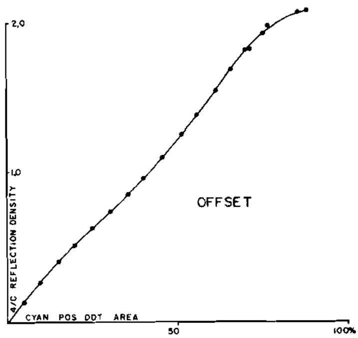

FIG A6

An immediate observation made of the two curves is that their respective shapes are very different. The Gravure curve has a dramatic toe and shoulder while the Offset curve is more linear, flattening out in the shoulder.

The author's explanation for this phenomenon relates to the different measuring scales used. Both transmission and reflection density are logarithmic measurements, while dot area is linear. If the Gravure curve was plotted in log/log paper and the Offset curve was plotted on semilog paper, the respective curve shapes would be more similar. See Figures A7 and A8.

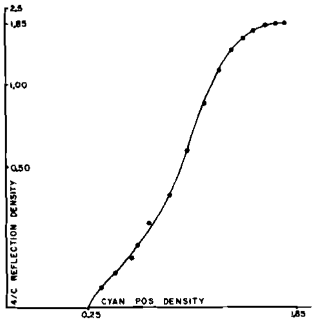

FIG A7

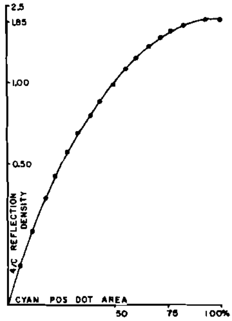

FIG A8

Looking at these two curves, it can be seen that the curves shoulder in a similar manner but bow in opposite directions in the midtones. It would appear then that a simple midtone correction would be all that is necessary in a tone correction LUT.

What must be realized however, is that pictorial data stored in a digital system is linear and not logarithmic. The tone range for each color is divided into 256 discrete levels described in one byte of data. These system levels are then retranslated to continuous tone density or dot area at exposure or readout on the monitor. To work with a digital system then, linear graphing is more appropriate.

Referring back to Figure A4, it can be seen how the linear correction curve is derived. It can also be seen that accurate control of the diffuse highlight is critical. In the Group V standards, the first "assured" printing density from film is .34 with a nebulous fade off area down to .25. Correlation of minimum printing dot to minimum printing density in the diffuse highlight could make or break the quality of either reproduction.

Further analyzing the correction curve, it can be seen that between the diffuse highlight and quarter tone areas, roughly a Gamma 1 ratio exists. Throughout the midtones, large changes in dot area result in small changes in continuous tone density while in shadow areas, large changes in dot area correlate to smaller changes in continous tone density. Obviously a simple linear correction or bow in the midtones will not do.

It was the author's contention to develop these curves by plotting the cyan film dot area or density against the four color overprint. Alternatively, four separate tone reproduction curves could have been developed plotting each color film dot area or density against its respective single color printing density. It was felt that to do this might cause color shifts. Trapping and additivity failure is also better taken into account by the method used.

To date, the objective of a tone reproduction correction is to achieve an identical tone reproduction curve (original art to press sheet) for each process. In the case of Group V inks on Group V publication stock and SWOP Offset conditions, the Dmax on both press sheets (four color overprint) is roughly equal. For Group I inks printed on roto news stock, the Dmax is much lower. In this case, a linearly compressed curve from the Offset or Group V condition may not produce the most visually pleasing results.

Empirical data must be developed to determine differences in desired tone reproduction among radically different printing conditions. In such a case, a desired curve may be substituted for the 45 degree transfer curve in the Jones Diagram.

B. GRAY BALANCE

The balance of color inks to one another throughout the tone range is normally referenced to the gray scale. Since by definition gray consists of equal reflections of red, green, and blue light, maintaining a neutral color in a reference gray scale reproduction should provide balance throughout the picture.

As previously mentioned, gray balance is achieved in Offset printing through the screening process, while in Gravure, the balance is achieved in cylinder engraving. Group V standards call for equal densities on film to result in gray on paper.

Working with this standard, gray balance correction curves are easily derived. A look up table in the Scitex system works in all three (or four) colors at once with individual control of each separation. Taking Offset gray balance values from a typical shop standard (no standard exists in SWOP) a sample table can be developed as follows (Note: Values are in system levels).

	CYAN	MAG	YEL		CYAN	MAG	YEL
SH	15(94%)	31(88%)	26(90%)	=	15	15	15
3/4	56(78%)	87(66%)	82(68%)	=	56	56	56
MT	84(67%)	115(55%)	112(56%)	=	84	84	84
1/4	171(33%)	191(25%)	186(27%)	=	171	171	171
HL	240(6%)	247(3%)	247(3%)	=	240	240	240

The table may be plotted for interpolation of interim values or the system will interpolate linearly when using the command creating an LUT.

C. Color Correction

To adjust for proportionate reflection/absorption inaccuracies of printing inks, color correction is performed. Where one process color behaves as if contaminated by another, a lesser amount of that ink must print in overprints of the two colors. Color correcting masks or masking signals in a scanner accomplish this requirement.

Calculations for the amount of correction needed are based on trichromatic densitometer readings of the printed process colors. Both the Neugebauer and masking equations provide a mathematical method for equating color in the original to quantities of C,M,Y in the reproduction.

Both these methods in effect convert the original data base (analog densities of the original art) to printing values (dot area or transmission densities).

The GATF color triangle developed by Frank Preucil provides a convenient method to determine mask percentages for color correction based on hue error and grayness factors of printed ink films.

To adjust for color correction requirements between two ink sets or printing conditions, it must be noted that the data base is now discrete C,M,Y values already corrected for one condition. What must be determined is the difference in correction requirements between two print conditions and how to adjust for this difference.

Look up tables such as mentioned for tone correction and gray balance are not color selective. That is, a given value of one color will change to new value regardless of other color values. Color correction, on the other hand, must take into account the relative values of all three colors in any pixel and adjust accordingly.

A three dimentional LUT rather than a simple look up table is needed. The program must work in such a way that whenever two color values overprint, one or the other is reduced (or enlarged) by the amount of change proportionate to both values.

Six ratios may be established which correlate to the six theoretically needed masks for color correction.

d = $\pm$ Mag in Blue	(C,M)		g = $\pm$ Yel in Red	(M,Y)
e = $\mp$ Yel in Green	(C,Y)		h = $\mp$ Cyan in Green	(C,Y)
f = $\mp$ Cyan in Blue	(C,M)		i = $\mp$ Mag in Red	(M,Y)

For any pixel then, a new value is found for each color.

C, M, Y = Existing Values
C', M', Y' = Corrected Values

One approach can be taken using the appropriate ratio based upon a color decision of the individual pixel. For each prime value there are two choices. For example, C' is the result of factor f or factor h. To chose which factor is correct, the computer must decide if the pixel is more bluish or more greenish.

The formulas for each prime color would be as follows:

$$C' = C + \left[C\left(\frac{fM}{100}\right)\right] \cdot \left[\frac{M-Y}{100}\right] \quad \text{if } M \geqq Y \qquad M' = M + \left[M\left(\frac{iY}{100}\right)\right] \cdot \left[\frac{Y-C}{100}\right] \quad \text{if } Y \geqq C$$

$$C' = C + \left[C\left(\frac{hY}{100}\right)\right] \cdot \left[\frac{Y-M}{100}\right] \quad \text{if } Y > M \qquad Y' = Y + \left[Y\left(\frac{eC}{100}\right)\right] \cdot \left[\frac{C-M}{100}\right] \quad \text{if } C > M$$

$$M' = M + \left[M\left(\frac{dC}{100}\right)\right] \cdot \left[\frac{C-Y}{100}\right] \quad \text{if } C > Y \qquad Y' = Y + \left[Y\left(\frac{gM}{100}\right)\right] \cdot \left[\frac{M-C}{100}\right] \quad \text{if } M \geqq C$$

Working directly with the masking equations can also be done. However, they are linear in nature. The proportionality of all color values in the pixel to each other is not properly accounted for. Refinement of color correction mathematics is under development.

The derivation of the ratios themselves is based on trichomatic densitometer readings of printed ink films. Using the same logic as used in the Preucil system, hue error and grayness factors for both ink sets can be calculated and plotted in a color triangle. The difference in plotted data then correlates to differences in mask percentages. These differences in mask percentages might conceivably be used as ratios for correction.

Calculations for hue error and grayness were made from reflection readings of two ink sets. Measurements of Group V inks were taken from page 25 of the GTA Group V standards booklet and Offset measurements were taken from a press sheet allegedly printed to SWOP standards.

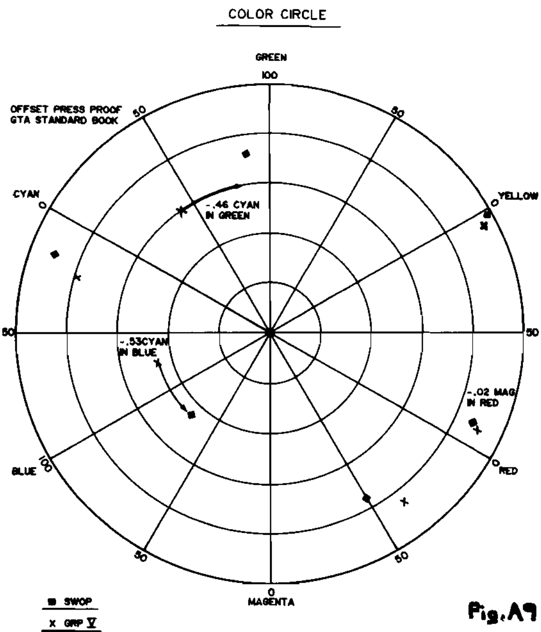

Fig. A9

Figure A9 is a GATF color circle showing hue error and grayness both for primary colors as well as for overprints. It is easily seen that the overprint differences are much greater than the primary differences. Apparent trapping, additivity, and other factors contribute to this condition. Considering that it is the Red, Green and Blue which actually need to be controlled, it is the author's contention that it is the differences in overprints rather than primaries which should be programmed into any color correction conversion program. Note that despite the fact that the Gravure magenta is more yellow than the Offset magenta, the red overprints are nearly identical. In fact, the Gravure red is slightly less orange then the Offset red. A more significant difference exists in the green and blue overprints. The Group V green is "bluer" and grayer than the SWOP green. The Group V blue falls on the cyan side of the blue axis while the SWOP blue is on the magenta side.

It can be reasoned then, that to convert from SWOP to GROUP V, cyan must be reduced in blues and greens while a slight reduction of magenta in reds is called for. Though the grayness factor is not directly taken care of by this two color overprint consideration, adjustment for grayness falls into place. For instance, cyan is reduced in reds since most red colors have cyan and magenta components.

There is no direct mathematical correlation between overprint hue error calculations and correction factors as explained here. It seems logical however, that the magnitude and direction of corrections can be derived.

Early experiments with this program, where only color differences were isolated using Cromalin toners, showed that approximately 1/2 the calculated hue error difference was the correct factor for color correction.

D. Undercolor Removal and the Black Printer

Generally, Offset publications make use of a short range skeleton black while Gravure black separations are full range. Requirements for undercolor removal between the two conditions are also slightly different.

Working from an analog signal, scanners traditionally have generated the black printer, with or without UCR, using three color data. Theoretically, no new picture information is contained in the black printer which cannot be derived from three color data.

The Scitex system has had from its outset, an under color removal program which also generates a black from existing three color data. This UCR program is performed as an extra data processing step just before exposure. Since UCR on the scanner occurs during the scan, most users have preferred to use scanner UCR. The drawback to this in making any conversion is that where UCR has already been done, three color data has been suppressed.

Recreating three color data from black data, where a lessening of UCR is required, would take considerable experimentation and a special program. When conversions are likely to be needed, it is best to scan in data without UCR and allow the system to perform this function separately for the two print conditions.

The Scitex UCR program is achromatic by nature, meaning that the colors are not only reduced in gray areas but gray or neutral components are removed from all color areas.

As of the writing of this paper, the printing industry shows great interest in various approaches to achromatic color removal. The state of the art is dynamic and for the present, neither SWOP nor GTA Group V standards involve specifications for achromatic type of color removal.

Until publishers, advertisers, printers and trade shops have more experience in dealing with this type of color removal performed on digital imaging systems or new generation color scanners, the "old" UCR requirements and black printers must be matched as close as possible. As achromatic color removal becomes more familiar, the same UCR requirements may be found suitable for both SWOP and GTA Group V standards.

Experimental Results

To develop working conversion data for each of the four factors mentioned, it is necessory to isolate each factor and test them individually before combining functions.

Testing began with the problem of color correction. A program within the Scitex system based on the masking equations looked like it might solve the color Correction problem. In order to isolate color correction requirements from other factors, two sets of Cromalin toners were used. A proof made from the test form (scanned for SWOP) served as the control. Calculated hue error differences of the Cromalin overprints were entered into the experimental program and a new set of films was generated. From these films two new Cromalin proofs were made, one with SWOP toners and one with Group V toners. The results showed that the direction of the correction was correct although somewhat excessive. Performing the experiment again using one half the calculated hue error differences proved much more encouraging.

Hue and grayness differences between SWOP and Group V printed ink films were found to be much greater than SWOP and Group V toner sets. Working with calculated differences in ink sets, further experimentation revealed discrepancies in results. The proportionate ratio approach for color correction presented in this paper was not used in the initial experimental program. Further testing using this theory is under way.

In the longer run, development of a non-linear, more sophisticated color correction program is under investigation. CMY values may be converted to other types of color notation which could lead to a single transformation program accommodating all four conversion requirements at once.

Tests of the tone reproduction procedure have produced promising results. However, inconsistencies in the proving or printing process require an inevitable amount of trial and error.

Testing in general for the conversion process tends to be slow. The expense of gravure printing makes scheduling of test runs costly and infrequent. Many of the tests for gravure print results had to rely on pre-press proving mechanisms instead of the actual prints. Recent advances in pre-press proving for gravure are encouraging. However, accurate correlation of pre-press proofs to gravure press runs observed during the testing period was left wanting.

Once the isolated factors of tone reproduction, color correction, grey balance, and UCR are sufficiently quantified, the combined effects of corrections on each other must be evaluated. In the forthcoming year, extensive testing will continue so that a workable set of parameters for SWOP to Group V conversion will be established. Success in making conversions without extensive further corrections must depend on the printing conditions of both Offset and Gravure matching published standards and remaining consistant.