USING KODAK CUSTOMIZED COLOR ANALYSIS TO DEVELOP STANDARD SEPARATION CURVES

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Abstract: Kodak's new Customized Color analysis program which takes readings from a printed test object using a spectrophotometer, calculates press performance data, ink color measurements, and separation curves. This information was generated for each of 28 U.S. publication printers involved in Phase I of the 1983 Graphic Communications Print Properties test. The negative separation curve data for normal copy, a skeleton black printer and 280% undercover removal, was tabulated for each of the 26 printers. Using standard statistical procedures, the means and standard deviations were derived for six aim points along the separation curve. Average curve values were derived for the cyan, magenta, yellow, and black separations. An experienced trade separator separated two different subject transparencies using a scanner adjusted to the derived average aim points and to aim points normally used for magazine advertising. The two sets of separations were then printed at four of the publication printers involved in the Phase I test.

The derived separation curves exhibited an improvement in tone reproduction over the previously used separation aims. This was further verified through a comparative evaluation of the printed results by the participants in the Spectrum Conference.

Using KODAK Customized Color Analysis

Many of you are familiar with the KODAK Customized Color Analysis program. Dick Maurer, who has retired from Kodak Research Laboratories, reported to this association on the early-phase development of the program in 1982.

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Since then, the program has evolved into -- and, in fact, beyond -- the practical testing phase.

The Customized Color program includes a thorough, spectrophotometric analysis of a printed test target. A mainframe computer then processes the analytical data. The computer interpolates the data to prescribe separation aim points which will produce the best results on-press under the test conditions.

Today, I would like to report the results of a test undertaken by the Graphic Communication Association that involved the KODAK Customized Color Analysis program.

Eastman Kodak Company participated as a member of the Graphic Communication Association Print Properties Committee. Other manufacturers and other methods of analysis were also involved in this 1983 Phase I test.

Most important, a broad cross-section of web offset publication printers took part in the test.

We were asked by the committee to apply the new KODAK Customized Color Analysis to the printed results of 28 publication printers.

Certainly, our measurement would be useful for comparative purposes. As I mentioned, other testing methods were also involved in the tests.

Measurements of printed test objects by densitometers and spectrophotometers would allow an evaluation of printing conditions and ink color response.

Another goal GCA assigned to the tests was to determine whether standard separation curves could be derived from actual printed results. It was here that the KODAK Customized Color Analysis program could be particularly helpful.

It derives optimum separation aim points from printed results by applying computer logic that integrates and interpolates analytical data.

This logic accounts for the dynamic interactions among the cyan, magenta, yellow, and black printers. These interactions must be factored into the calculations as we work our way back to the optimum aim points.

From our experience with the Customized Color program, we were confident that separation aim points derived from a SINGLE set of test conditions could improve the printed product under those test conditions.

But only a broader-based test would reveal whether a LARGER sample of results could produce "standard" or "par" separation aims that could improve results over a broader range of conditions.

GCA addressed this issue in its 1983 Phase I test.

Before I present the results, a description of the KODAK Customized Color Analysis, the test procedure, and the method of analysis will be helpful.

The test target designed for the Customized Color program is 4-1/2 inches square. It contains 144 individual patches. Among these patches, there are:

-- black circles ...
-- single color solids ...
-- 2-, 3-, and 4-color solids ...
-- near neutrals ...
-- black and color scales ...
-- color tints ...
-- parallel lines ... and
-- concentric circles

These patches are scanned by a spectrophotometer. It reads each patch at 20-nanometer increments throughout the visible spectrum from 400 to 700 nanometers. It generates more than 2,300 readings.

This data is processed by a mainframe computer at Kodak.

Analytical data is printed out in tabular and graphic form.

Reflection densities of solid ink patches are included in both "conventional" and "narrow band" (SPI) densitometer values.

The percent of effective trap of the three process color inks is recorded. This is related to the color sequence used for the test.

The physical dot gain for each of the four inks (cyan, magenta, yellow, and black) are tabulated and plotted along the halftone reproduction scale at 10, 30, 50, 70, and 90 percent. As expected, the maximum dot gain normally appears near the 50 percent dot values, where the maximum dot edge or perimeter occurs.

The directional portion of dot gain is separated and indicated as slur. Both the amount and the direction of slur are calculated.

Ink color performance is also analyzed. The reflection densities of the primary colors -- black, 2-, 3-, and 4-color overprints -- are tabulated and plotted throughout the visual spectrum. The paper is analyzed in the same way.

Graphically, this data is plotted on the Standard Color Triangle and on the C.I.E. Lab Color Volume chart.

Finally, and most important, separation curves are specified for the test conditions under which the test target was printed.

To derive those curves, the computer specifies the percent dot in the film negative required to provide optimum gray balance and tone reproduction. Aims are indicated for the five points represented as A, -M, M, -B, and B on this sheet.

Several types of curves may be developed depending on the type of original copy ... the tone range of the original ... the separation method ... the type of black printer used ... and the amount of undercolor removal.

That, briefly, is how KODAK Customized Color Analysis works.

For its test, GCA selected 28 heatset web offset publication printers.

Each printer received a test object. It included all of these test targets ... and four halftones.

Of the 28 printers in the test, 24 asked for negative test forms and 4 asked for positive forms.

Each printer was asked to make a set of plates using the same plates normally used for publication work. Normal plate exposures and processing procedures were to be used.

The processed plates were then mounted on a standard publication press that was operating normally and producing saleable work.

It was critical that the test be run under normal conditions, without trying to improve conditions or performance for the test. A typical publication paper stock was to be used.

During makeready, the printer was asked to achieve ink density levels near to standard web offset proofing densities and print 500 sheets.

The following data indicates the variation in equipment and materials used by different printers during the test. As you can appreciate, there is a high degree of variability under these test conditions.

Variables

- 5 press manufacturers
- 15 paper stocks
- 8 paper weights
- 9 blankets
- 6 plate manufacturers
- 11 fountain solutions

GCA collected the samples from each of the printers and returned 5 sequential samples to Kodak for analysis. The 5 sheets were inspected using a densitometer and a magnifying glass. A sheet which was considered average and representative of the 5 sheets was selected.

The KODAK Customized Color test target was then cut from the selected press sheet and analyzed.

In order to compute separation aims, certain parameters must be established. These are the parameters we used to produce a COMMON set of separation curves.

As you'll recall, aim points can be customized to other choices in each of these categories. But the goal, in this case, was a "standard" curve that would improve results for ALL 28 printers. Actually, two printers submitted their printed sheets too late to be included.

Printed test targets from the remaining 22 negative plate printers and 4 positive plate printers were analyzed. Because there were only 4 positive plate printers, the positive percent values were converted to negative values.

After we had completed the Customized Color Analysis for all 26 printers, we applied statistical methods. We calculated the mean (average), standard deviation, and range of results.

Statistical calculations were applied to prevent abnormal deviations from influencing the results.

Values above the mean-plus-one standard deviation were excluded. Then the mean and standard deviation were refigured, using the acceptable range for the final calculations.

Specifically, some of the printers had excessive dot gain, which would have required a significant increase in the negative percent dot value.

Of the 26 printers in the sample, 16 percent were beyond the mean-plus-one standard deviation for cyan ... 11 percent for magenta ..., 17 percent for yellow ... and 6 percent for black.

To illustrate the effect of our statistical approach, here you see a comparison of average dot values in the negative at the 1.30 -- midtone -- M step. The unadjusted average for the entire sample of 26 printers appears first. On the right are the calculated values.

We applied this approach to the characteristics of ink densities, dot gain, slur, trap ... and, most important, to the separation aim points.

Here are the averages for the solid ink densities of cyan, magenta, yellow, black, the 3-color black, and the 4-color black. These are reported in terms of conventional and "narrow band" (SPI) densitometry. You will note that there's a difference between them -- in the cyan, magenta, and yellow.

From Conventional Densitometers

Color	Average	Acceptable Calculated Range* High	Acceptable Calculated Range* Low
Cyan	1.31	1.40	1.22
Magenta	1.36	1.45	1.27
Yellow	0.92	1.01	0.83
3-Color	1.32	1.39	1.25
4-Color	1.90	2.00	1.80
Black	1.50	1.63	1.37

From S.P.I. Densitometers

Color	Average	Acceptable Calculated Range* High	Acceptable Calculated Range* Low
Cyan	1.35	1.44	1.26
Magenta	1.45	1.55	1.35
Yellow	1.26	1.41	1.11
3-Color	1.32	1.39	1.25
4-Color	1.90	2.00	1.80
Black	1.50	1.63	1.37

*Range is adjusted average ± one standard deviation.

Keep in mind that Customized Color Analysis uses the more accurate spectrophotometer color readings to derive separation aim points. But densities are reported in conventional and "narrow band" readings, since printers are using these instruments in their plants.

We also focused on physical dot gain of the 50 percent dot. This is where the effect of dot gain is most evident. And these are the results.

Negative Dot Gain at 50%

Color	Average	Acceptable Calculated Range* High	Acceptable Calculated Range* Low
Cyan	17	22	12
Magenta	20	26	14
Yellow	16	22	10
Black	18	26	10

Positive Dot Gain at 50%

Color	Average
Cyan	12
Magenta	16
Yellow	11
Black	13

Because of only four positive tests, no range was calculated.

The amount of slur was another factor. As I have mentioned, this is the directional aspect of dot gain.

Slur

Color	Average	Acceptable Calculated Range* High	Acceptable Calculated Range* Low
Cyan	5	10	0
Magenta	7	12	2
Yellow	6	12	0
Black	4	11	0

*Range is adjusted average ± one standard deviation.

We also applied these calculations to the percent trap of the three 2-color overprints and the one 3-color overprint.

GCA TEST AVERAGES

Trap Values

Color	Average	Acceptable Calculated Range* High	Low
1st Trap (M/C)	76	93	59
2nd Trap (Y/C)	84	101	67
3rd Trap (Y/M)	64	78	50
4th Trap (Y/V)	57	66	48

*Range is adjusted average ± one standard deviation.

The goal was to compute separation curves, and this is the distilled data on which those curves were based.

Computed Separation Curves for Negatives**

Color	Density of Original Transparency	% Dot in Negative	Acceptable Calculated Range* High	Low
Cyan	.30	95	99-91	
	.60	72	67-77	
	1.30	34	39-29	
	2.00	28	32-24	
	2.40	27	31-23	
	2.80	26	30-22	

Color	Density of Original Transparency	% Dot in Negative	Acceptable Calculated Range* High	Low
Magenta	.30	95	99-91	
	.60	81	86-76	
	1.30	48	54-42	
	2.00	42	37-47	
	2.40	40	35-45	
	2.80	39	34-44	
Yellow	.30	96	97-95	
	.60	85	89-81	
	1.30	50	44-56	
	2.00	44	49-39	
	2.40	43	48-38	
	2.80	42	37-47	
Black	.30	100	100-100	
	.60	100	100-100	
	1.30	85	89-81	
	2.00	38	46-30	
	2.40	21	16-26	
	2.80	10	10-10	

*Range is adjusted average ± one standard deviation.

**These curves were computed for separations from normal image transparencies with a skeleton black printer and undercolor removal of 280%.

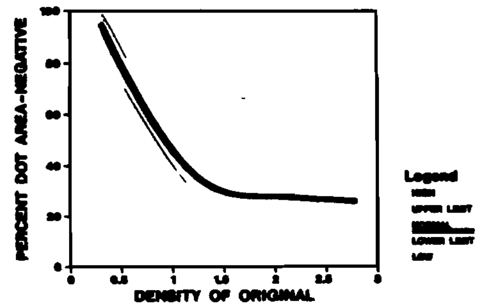
The first column shows the density of the original transparency. On the right, you see the percent dot assigned to reproduce that density.

If you plot density of the original transparency ... versus percent dot in the negative ... you will produce an average separation curve for each of the four colors.

To simplify, let's look at a graphic presentation of this data for each color printer.

Below is the cyan printer result. The high and low red lines are the actual outer limits -- or range -- of the data gleaned from the printed results.

GCA CYAN PRINTER RESULTS

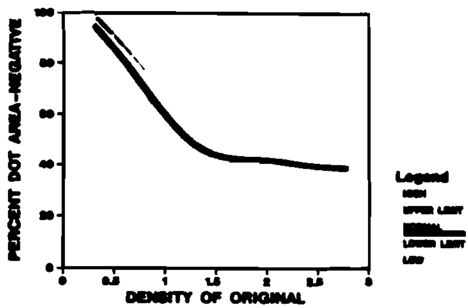


Take these ranges ... apply statistical analysis to eliminate highs and lows ... and you now need only be concerned with the green area.

Determine the mean or average of the green area, and you have the average cyan curve, represented by the blue or "normal" line in the center.

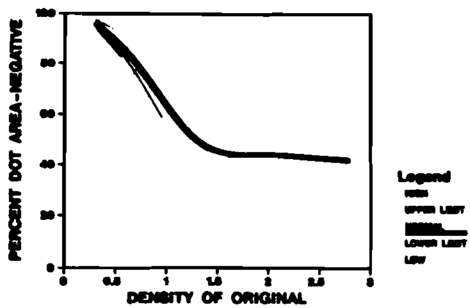
Here is the magenta printer result ...

GCA MAGENTA PRINTER RESULTS



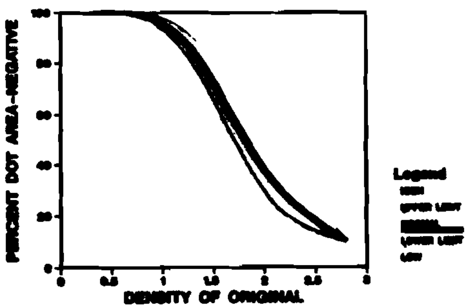
the yellow printer result ...

GCA YELLOW PRINTER RESULTS



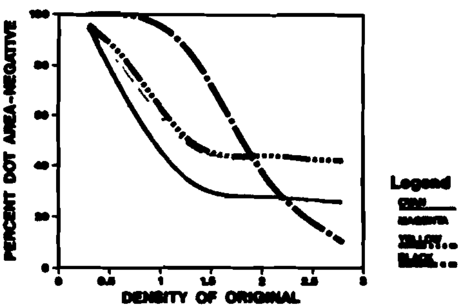
and the black printer result.

GCA BLACK PRINTER RESULTS



Strip away the ranges, and you have the GCA normal "par" separation curves, as seen below.

GCA NORMAL PAR SEPARATION CURVES

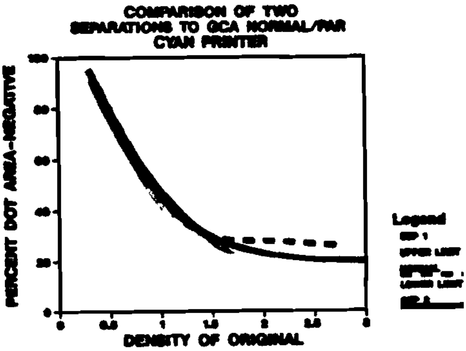


To test the validity of using a statistical average to calculate standard or "par" separation curves, the average readings were given to 2 major national magazine separators for a practical test.

Each separator was instructed to make two different sets of scanned separation negatives.

The first set was scanned to values that were normally used by the separator for national magazine advertising. The second set was scanned to the standard or "par" values from the GCA test.

If we look at the curves used for the cyan printer, you see that there is a definite difference. The light and dark lines are the curves the 2 separators normally used ... compared with the GCA "normal" or "par" curve.



Both sets of halftones from each separator were duplicated and stripped into flats that were used in the original test.

Four of the printers who participated earlier were asked to reprint the job matching SWOP densities and all printing conditions of their initial run. They were then asked to print to their normal production densities and attempt to match a supplied proof.

The printed results were measured by another KODAK Customized Color Analysis.

Three of the four printers were within the acceptable range established for dot gain. The fourth sample had more gain and was outside the acceptable range, particularly in the magenta.

The appearance of the three samples that were within acceptable printing conditions (as statistically defined by the test) was compared to the original and to off-press proofs.

Comparisons were displayed at the 1983 Spectrum meeting in Phoenix, Arizona. The consensus of participants at Spectrum was that the halftones separated to the GCA "standard" values matched the original better than the halftones separated to the national color separators' normal values.

Before I explore the potential applications of standard separation curves, let me stress several points.

We should keep in mind that these curves were developed for web offset publication printers using standard publication offset stocks.

Different standards may be required for sheet-fed presses ... for newsprint ... and for high-grade enamel stocks.

We need to ask whether our selection of parameters for separations were the best choices.

Variability during the press run can conceivably skew the results of these tests. We need to minimize variability so that the printed sample is more truly representative of the press conditions.

The role of the proof is another important issue. Since dot gain is factored into the separation films, proofs from these films will NOT have a pleasing appearance unless they're run on a production press. If we cannot simulate the effect of this degree of gain by standard proofing methods, how do we get the client's agreement to print these films?

Certainly, there are issues to be addressed before standard separation curves become practical.

But we believe there are compelling benefits that follow from the ability:

-- to measure the conditions on a group of presses ...

-- to determine acceptable averages and ranges ...

-- and to develop standard separation curves for those conditions.

Printers who receive films from more than one separator for the same job would be able to produce higher quality. There would be no need for "averaging" color on-press to the lowest-quality denominator.

The printer should experience reduced makeready time and less running waste.

Separators would have specific numbers for scanning color, eliminating the need to develop separation curves by trial and error.

The printing buyer would see improved quality and consistency.

Conceivably, there would be better communications between the buyer, ad agency, the separator, the publisher, and the printer through the use of a common set of values.

We believe the merits of this approach will become even more convincing as the future provides a larger sample for analysis ... and an expanded base of experience.