COMPUTER CALCULATED OPTIMUM BLACK PRINTER

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Abstract: Extended black printer concepts and benefits are well known. A new and practical method for achieving these benefits is presented.

Spectronics has designed a black printer test target and a computer program for black printer calculations. Actual press data and the computer program are used to calculate optimum separation requirements for quality and economy.

The test target data is analyzed to provide:
- maximum print quality
- minimum 3-color ink usage
- correct tone reproduction for the entire tonal range of cyan, magenta, yellow AND key.

The optimization is based on the user's choice of objectives:
- specified total film build-up

-or-

- specified maximum print density

-or-

- specified cyan film shadow value

The computer not only performs these calculations, it also validates that the user-specified objective is achievable.

This paper reviews tone compression, conventional calculation of separation film requirements, and the impact of the black printer on film requirements. Then the new black printer test target and related calculations are presented.

Introduction

Many theories exist to help create quality color separations and quality color printing. Emerging computer

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techniques allow these theories to become practical tools.

One of the most critical requirements for producing quality color printing is the compression of the tonal range of an original into the range of the print process. This paper assumes that any normal original has an optimum mapping of original densities into print densities. The specific mapping is a function of the range of the original and the range of the print process. This mapping will be referred to as a tone reproduction model.

Traditional Calculations

For optimum reproductions, separation films must relate densities of an original to the print densities called for in the tone reproduction model. For a given set of film values, print densities will vary as a function of press, paper, ink and process conditions.

Consider the steps required to print a neutral picture using a 3-color process. The characteristics of the process could be empirically established by printing a test form with a full range C plus balanced M and Y. Suppose the maximum print density is 1.4 and the original has a range of 3.2. For any copy density, the appropriate print density can be determined from the tone reproduction model. The film values and corresponding print densities from the test form define the characteristics of the process.

The separation film requirements for this original are calculated from these two relationships. For example, the tone reproduction model shows that a 1.2 original density should reproduce as a 0.7 print density. The characteristic curve of the process specifies a C film value of 64 percent to produce the desired 0.7 print density. Repeating this series of calculations produces the desired separation film gradations.

There is nothing new in this approach. Given the tone reproduction model and the process characteristics, separation film requirements can be calculated exactly. This is the highly recommended Jones diagram approach. However, until recently, it was rare to perform these calculations for every original -- it is too time - consuming. Computer-based tools like SCANTRONICS now do these calculations so quickly that theory can become practice. It is now practical to calculate exact separation film requirements for every original, calculating for copy and process characteristics.

Addition of Black Printer

What happens when the black printer is added to the preceding example? There are at least three answers, depending on what you want to happen:

Case 1 - Increase print contrast, no reduction in CMY ink use (Figure 1)
Case 2 - Increase print contrast and reduce CMY ink use (Figure 2)
Case 3 - Maintain 3-color print contrast, reduce CMY ink use (Figure 3)

The shaded regions of Figures 1, 2 and 3 represent print density produced by the black ink.

Each of these cases has an effect on the tone reproduction model. Cases 1 and 2 increase the print contrast. Therefore, compared to the 3-color example, any original density will reproduce a higher print density. Case 3 should reproduce the same print densities as the 3-color example did. In other words, with a known 3-color print contrast, identical results are possible with reduced 3-color and some amount of replacement black. The separation films must be different; the printed results should be identical.

Figures 1 and 2 show a 4-color tone reproduction curve for a print range of 1.8. This printing would be judged to be higher quality than the examples that produced a 1.4 print range. Cases 1 and 2 should produce identical printed results using properly produced separation films. Of course the separation films must be different.

The separation film requirements are different for each of these cases (and for the 3-color example). Increased print contrast requires "heavier" CMY films in the region where no black is printed. In the region where black is printed, the CMY film gradations must be calculated to produce the required print densities when overprinted with the specified amount of black.

Cases 2 and 3 referred to reduced CMY ink use. The traditional way to quantify reduced 3-color ink use is by specifying cyan's normal shadow film value, cyan's shadow film value with UCR, and the start point where the reduction in C begins.

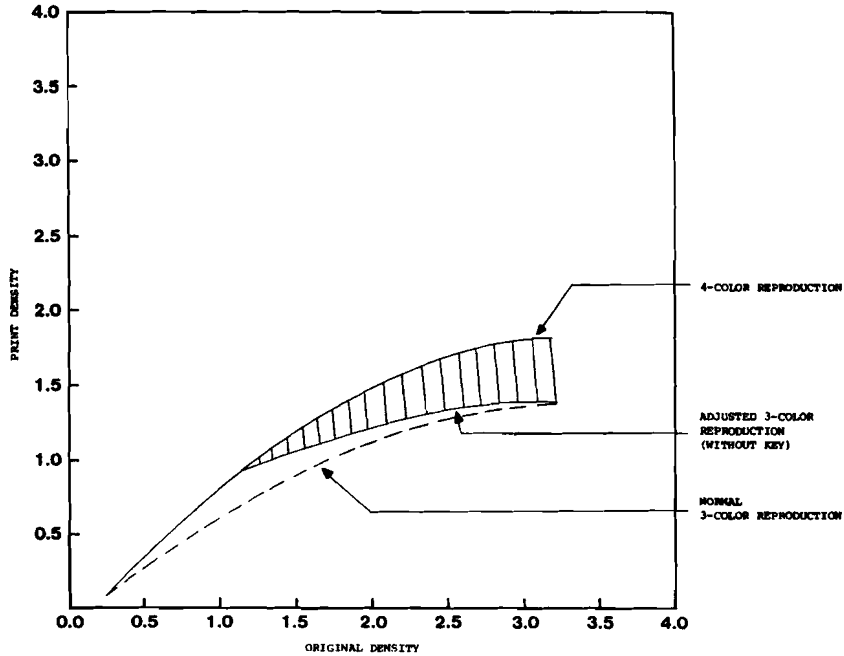

Figure 1. Increase print contrast, no reduction in CMY ink.

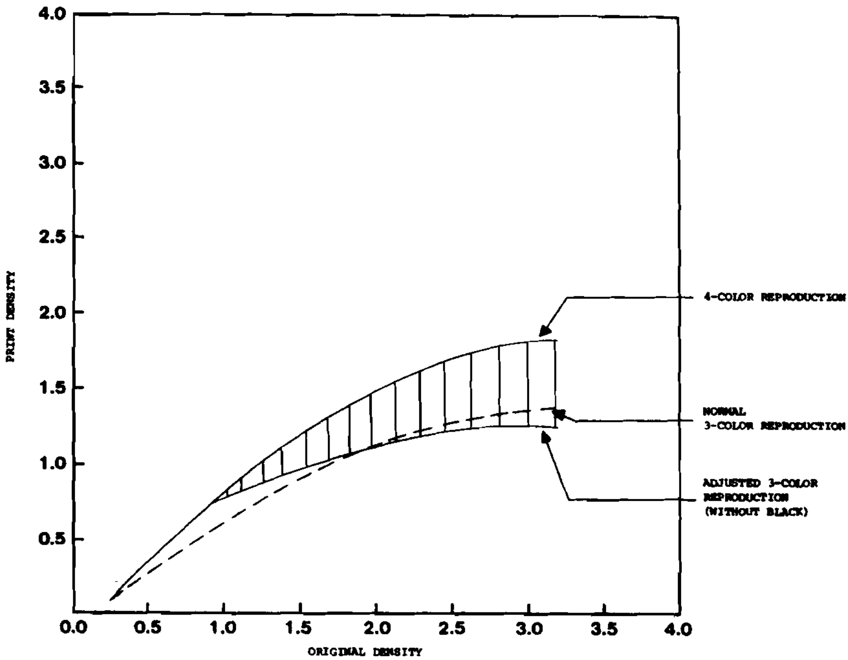

Figure 2. Increase print contrast and reduce CMY ink.

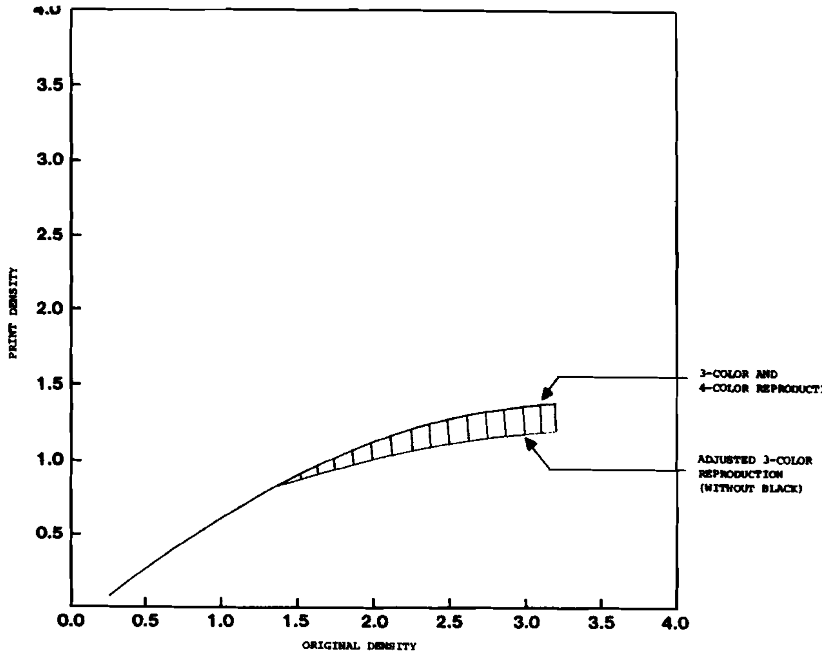

Figure 3. Maintain 3-color print contrast, reduce CMY ink.

Black Printer Test Target

To properly calculate separation film requirements for varying amounts of black, additional data are required. Specifically, for any feasible print density and specific level of 3-color film values, how much black is required?

To obtain the required empirical data, a range of 3-color overprints in combination with a range of black values was designed into a test target. The test target consists of a grayscale for C, M and Y overprinted in 15 rows. The black printer grayscale is printed across the CMY grayscales in 15 columns. The overprints create a 7.5 by 7.5 inch image which contains 225 combinations of black and 3-color neutrals.

On the press sheet, (Figure 4) the lower left corner of the target represents fade-off. The area beginning in the lower left corner and continuing straight up, represents increasing 3-color film values. The area from the lower left corner and continuing to the right, represents increasing black film values. And finally, the area from the lower left corner of the printed test target, moving diagonally to the upper right corner, represents increasing print density due to the uniform increase of film values in all three colors and black.

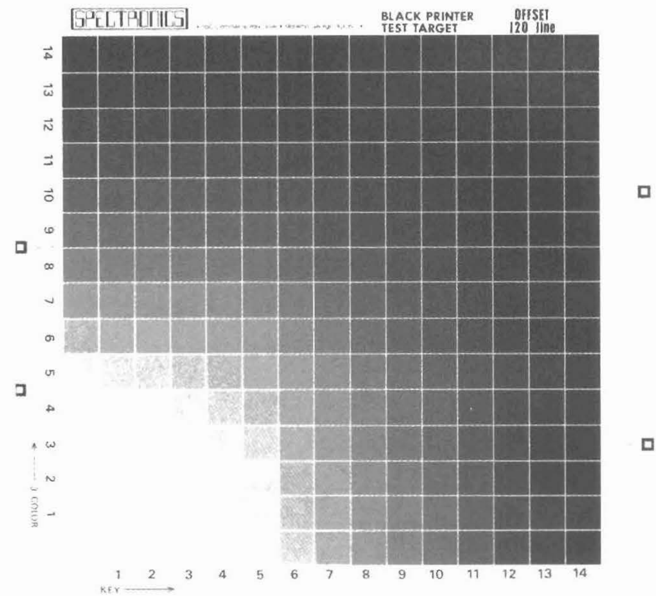

Figure 4. Test target press sheet.

BLACK PRINTER TEST TARGET

INCREASING 3-COLOR

CYAN FILM															
98	1.52	1.53	1.52	1.55	1.56	1.56	1.61	1.67	1.78	1.80	1.85	1.90	1.97	1.98	2.02
96	1.47	1.46	1.46	1.49	1.50	1.52	1.56	1.64	1.75	1.79	1.81	1.90	1.97	1.98	2.02
91	1.37	1.37	1.37	1.39	1.43	1.43	1.51	1.56	1.68	1.71	1.79	1.85	1.92	1.95	1.98
82	1.18	1.19	1.20	1.22	1.25	1.28	1.35	1.43	1.54	1.58	1.65	1.73	1.81	1.91	1.94
72	0.99	1.01	1.02	1.05	1.07	1.14	1.18	1.25	1.39	1.45	1.55	1.64	1.74	1.84	1.89
63	0.85	0.87	0.89	0.93	0.98	0.99	1.08	1.18	1.27	1.33	1.44	1.55	1.65	1.78	1.84
53	0.71	0.75	0.76	0.79	0.82	0.84	0.95	1.04	1.14	1.24	1.32	1.47	1.58	1.69	1.77
42	0.56	0.59	0.60	0.64	0.67	0.70	0.78	0.90	1.01	1.10	1.22	1.38	1.51	1.64	1.72
31	0.42	0.45	0.47	0.51	0.54	0.57	0.68	0.76	0.90	1.01	1.17	1.27	1.41	1.57	1.64
21	0.29	0.32	0.34	0.38	0.42	0.46	0.55	0.66	0.79	0.91	1.05	1.16	1.35	1.50	1.60
15	0.22	0.27	0.28	0.33	0.36	0.40	0.50	0.60	0.74	0.86	1.00	1.14	1.31	1.47	1.57
11	0.16	0.21	0.23	0.28	0.31	0.36	0.45	0.57	0.70	0.82	0.96	1.08	1.26	1.41	1.51
5	0.09	0.15	0.16	0.21	0.25	0.30	0.40	0.51	0.65	0.77	0.91	1.04	1.21	1.38	1.46
3	0.06	0.10	0.12	0.19	0.23	0.28	0.38	0.50	0.64	0.75	0.89	1.04	1.23	1.35	1.48
0	0.00	0.05	0.08	0.14	0.17	0.21	0.34	0.45	0.59	0.70	0.84	0.96	1.15	1.33	1.42
KEY FILM	0	4	6	11	16	21	32	43	55	64	72	82	91	96	98

INCREASING BLACK

Figure 5. Test target print densities.

The characteristics of the 4-color process are defined by the test form film values and the corresponding print densities. The print densities from an actual press run are listed in Figure 5.

Black Printer Considerations

The sample 3-color calculations so far are straight forward. But how can black requirements beyond traditional levels be calculated? Color scanners can produce good full-scale black printers, but:

Where should the black actually start?
How much black is desirable?
How much color should print?
Can "optimum" black be determined?
Can separation film quality be controlled?

Currently, black printer requirements are influenced by user-specification of one or more of the following parameters:

1. C film value at shadow with UCR,
2. K film value at shadow,
3. Maximum color build-up,
4. Desired print contrast,

plus:

Black starting point and
UCR starting point.

The motivation for expanding control over these parameters is well-known. There is significant potential for simultaneously increasing print quality (increased print contrast) and print economy (decreased ink use, increased press control). To date, traditional amounts of black printer have probably been the norm because traditional black is familiar and it is moderately successful.

The literature has referred for years to the potential benefits of expanding the use of black ink. What is required to make the extended use of black ink practical?

1. A method to fingerprint appropriate press and process characteristics.
2. A method to calculate separation requirements compatible with copy, press and dynamic black.
3. Appropriate scanner technology to achieve the desired separations.

Using the Test Target

The test target provides the necessary data on press and process characteristics. 225 elements in the target establish the relationship between all pertinent combinations of 3-color plus black, and the resulting print densities. Calculations for separation film requirements using extended black depend on the data obtained from the test target.

The test target makes it easy to quantify useful boundary conditions of the process. For example, the process in Figure 5 has a maximum 3-color print density of 1.52. Note that an equivalent shadow density can be produced with 21 percent C and 96 percent B. This demonstrates one measure of potential reduction in colored ink while maintaining shadow density.

(The example requires further analysis to establish whether separation films are actually feasible for these conditions.)

As another example, consider typical shadow film values: 74 percent C, 90 percent B, color build-up of 284. These film values produce a print density of 1.7 in this process. The test target shows numerous shadow combinations that maintain print density, reduce colored ink use and reduce color build-up. For instance, 55 percent C, 95 percent B produce a 1.7 print density with significantly reduced color ink -- color build-up is 232.

The test target can determine feasibility of user-specified parameters. For example, a print density of 1.8 is not feasible for this process if C is limited to 50 percent. The test target clearly shows this.

The test target does more than establish simple feasibility. The interdependence of user-parameters is easy to demonstrate. It is easy to examine different combinations of 3-color plus black that produce a user-specified print density (Figure 6). Or, for a specified level of maximum C, it is easy to see the achievable range of print densities possible by adding black (Figure 5).

Note in Figure 6 (and Figure 7) that the isodensity lines are slightly irregular. There are two reasons for these irregularities:

1. The test target is preliminary and the grayscale steps are not uniform.
2. The data are based on a single press sheet with no statistical smoothing.

The test target is useful to establish process boundary conditions and to measure the interdependencies of certain print variables. A more significant use of the test target is to calculate the complete black gradation required to satisfy feasible user-defined parameters.

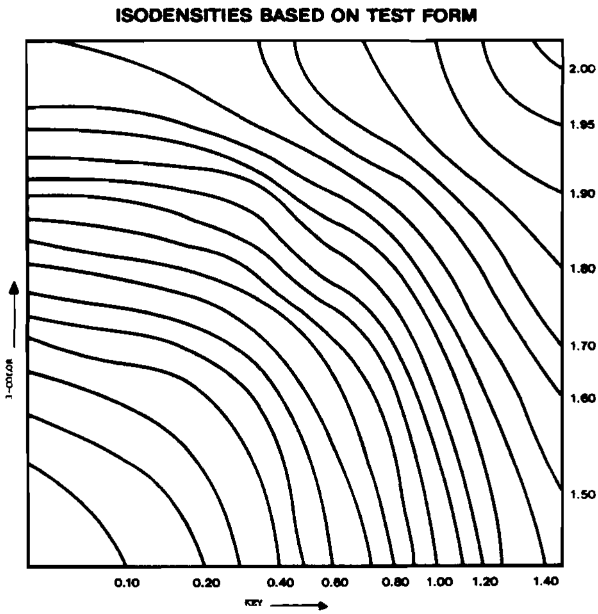

Figure 6. Isodensities based on test target.

Separation Film Calculations

User-parameters, directly or indirectly, establish what the process range is. Once the process range is determined, the tone reproduction model determines the print density required for any density in the original.

Suppose user-parameters are 65 percent maximum C and 1.8 print density. The test target confirms feasibility (so far). The desired shadow print density requires a 95 percent black (Figure 7). Film shadow values are now fixed. Assume a full range black (arbitrary). First printing and shadow endpoints are now fixed.

At this point, there are many combinations of 3-color plus black separation films that could theoretically produce the desired print densities. For scanner compatibility, the reduced 3-color film curves are based on the full-range 3-color film curves for this process.

In this example, the scanner's 3-color curves are determined from the tone reproduction model and from the 3-color characteristics of the process. The 3-color overprints of the test target determine the 3-color process characteristics.

ISODENSITIES BASED ON TEST FORM

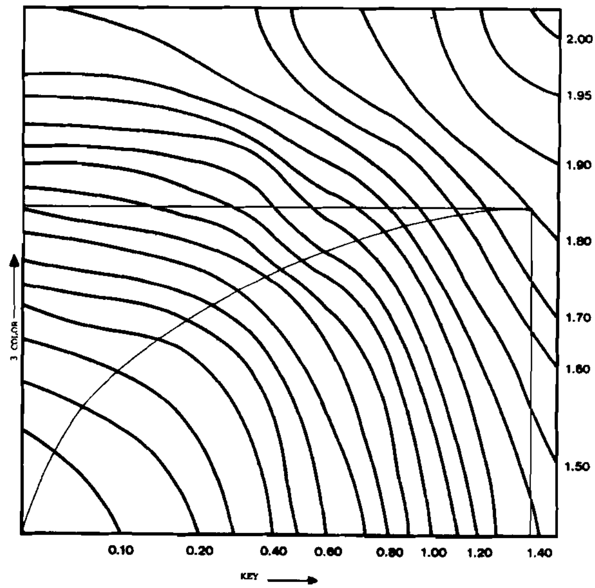

Figure 7. User-parameters are 65 percent maximum C and 1.8 print density. The desired shadow print density requires a 95 percent black.

For any copy density, the tone reproduction model determines the required print density. Suppose a 1.2 copy density should reproduce a 0.9 print density. The 3-color film curves call for a 67 percent C. With full range black and reduced C, scanners would reduce the 67 percent C to 42 percent C.

Two variables are now determined: print density of 0.9, and reduced 3-color ink values with 42 percent C. The amount of black to produce 0.9 print density must be calculated.

The 0.9 isodensity line on the test target represents all combinations of 3-color plus black ink that produce a 0.9 print density. The 0.9 isodensity line determines that 42 percent C with 21 percent black will achieve a 0.9 print density (Figure 7). Repeating these calculations for a series of densities in the original defines the separation film requirements in Figure 8.

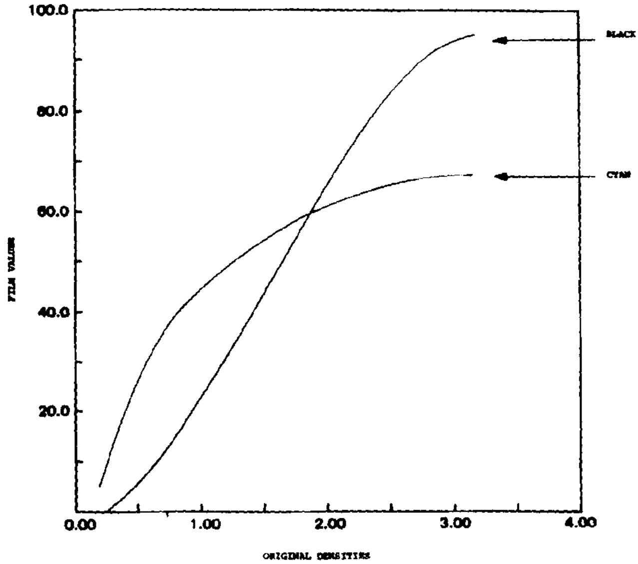

Figure 8. Separation film requirements calculated from the test target.

Achromatic Printing

Expanded control over black printer is a pre-requisite for successful achromatic printing. Techniques such as the ones described in this paper are essential to maintain control and quality in achromatic printing. For example, given a specified maximum black, the 3-color build-up required to maintain print quality can be determined.

As dependence on black printer increases, black printer gradation becomes more critical. Calculating black gradation for correct tone reproduction is essential if results identical to regular printing are desired.

Conclusion

Obviously, it is not feasible to do these calculations manually. The original SCANTRONICS pre-scan analysis has been extended to perform these calculations. The actual separation film requirements are calculated just as fast in this prototype version as in the original version.

The rhetorical questions regarding how much black and how much 3-color have intentionally been left unanswered. Appropriate answers depend on many variables. The important point to emphasize is that more black, less 3-color, better quality and economy are available, controllable and practical. Separation film quality and print quality can be controlled for a much more extreme range of black than is currently typical.