

INK TRAP MEASUREMENT

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Abstract: Densitometric methods of ink trap determination are discussed along with the notions of additivity failure and apparent trap. A new method of ink trap determination utilizing repeat inking patterns in laboratory experiments is introduced. Three ink trap equations are evaluated. The Preucil equation was found to be better than those proposed by Childers and Brunner. Standardized densitometer response or the use of spectrophotometers are suggested for improved ink trap measurement.

Introduction

Ink trap, or trapping, in multicolor printing concerns overlapping ink films. The control of the resulting overlap, or overprint, color is critical for the control of process color printing. Therefore, the measurement of ink trap is an important factor for the control of color printing.

In multicolor printing, ink trap percentage refers to how well a printed ink film covers a previously printed ink film relative to its coverage of an unprinted substrate. In other words, an 80% ink trap means that the ink film thickness of the second-down ink over the first-down ink is 80% of the thickness of the second ink on an unprinted substrate. The terms 'wet-trap' and 'dry-trap' refer to whether the first down ink film was wet or dry just prior to being overprinted by the second ink.

Some factors that influence ink trap include: tack of the first and second down inks; ink film thickness of the first and second down inks; ink-water balance (for lithography) of the first and

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second down inks; time between the first and second impressions; paper absorptivity; tack stability; paper hardness; press speed; and ink temperature (S.D. Warren Company, 1980; Watkins, 1983). An investigation of the reasons for variations in ink trap is beyond the scope of this paper.

Jorgensen (1982) recently reviewed optical, gravimetric, and miscellaneous methods of ink trap measurement. The optical method was found to have some strong advantages: it does not rely on the generation of special laboratory samples; the use of highly accurate balances, radioactive tracers; or the destruction of the sample. Optical determination of ink trap is routinely made by using a reflection densitometer to measure control targets on production press sheets. Such measurements are often part of a quality control program. The subsequent density values are converted to percent trap via an appropriate equation. Some densitometers will perform this calculation semi-automatically.

The major drawback to the densitometric method of ink trap determination is that it does not accurately measure trap. The balance of this paper will address the reasons for this inaccuracy, and explore methods for improving densitometric ink trap measurement.

Additivity Failure and Apparent Trap

The additivity rule states that the density of a combination of inks, as measured through a given filter, is equal to the sum of the densities of the individual inks measured through the same filter. In practice, the additivity rule does not hold. Table I illustrates additivity failure using typical yellow, magenta, and cyan inks and their two color overprints.

Yule and Clapper (1956) have detailed the reasons for additivity failure. A brief summary of these factors that apply to ink film solids is presented below.

1. First surface reflections. Matte surface papers and inks will cause light scattering from the surface of ink films and their overlaps. The

Table I

An Example of Additivity Failure

<u>Inks</u>			<u>Densities*</u>		
Cyan	Magenta	Yellow	Additive	Actual	Color
	0.67(BF)	0.87(BF)	1.54	1.41	Red
0.13(BF)		0.87(BF)	1.00	0.92	Green
0.44(GF)	1.22(GF)		1.66	1.37	Blue

*Density measurements were made through the filter complementary to the second down color. The printing sequence was cyan, magenta, and yellow.

overlaps will have a higher gloss and consequently will exhibit less light scattering than the individual ink films. Therefore, the densities of the overlaps will be greater than would be the case if the individual ink films and the overlaps had the same gloss.

2. Multiple internal reflections. Some light rays, upon entering an ink film, will be reflected back and forth between the paper surface and the surface of the ink film. Some of this light will not escape, thus contributing to higher density measurements. This factor is less important for thick ink films (overlaps) than for thin ink films. Therefore, the overlaps will have a lower density than would be expected from the sum of the individual ink films.

3. Opacity. Because the refractive indices of the pigments and vehicles in printing inks are not identical, the printed ink films will exhibit varying degrees of opacity. Therefore, the overprint color will tend to be dominated by the second down ink color.

4. Ink trap. If a different ink film thickness is transferred to a previously printed ink as compared to the unprinted substrate, the result is under or over trapping. The sum of the ink film thicknesses of the individual inks will not equal the overprint ink film thickness.

5. Back transfer effects. In wet-on-wet printing, it is possible for the second down ink to remove some of the first down ink, thus reduc-

ing the thickness of the first down ink in the overprint area. The second down ink will also be contaminated with the first down ink.

6. Spectral characteristics. The spectral response of the densitometer (especially the filter selection) will influence the additivity of the densities. Perfect additivity, a lack of additivity, or superadditivity may result from measuring the same sample through different filters.

Some of the above factors may cancel each other out, occasionally resulting in perfect additivity for a given set of conditions.

The key problem with the optical methods of ink trap measurement is how to isolate ink trap behavior from the other factors that contribute to additivity failure.

Laboratory studies of trapping generally employ some method of measuring the physical quantity of ink overlapping the first down ink. One such method is the gravimetric technique. This method involves weighing the printing plate before and after transferring the second ink to the first ink. The weight difference can be used to compute the actual thickness of the second down ink that was transferred to the first down ink. Such a study was conducted by Chen and Eldred (1972).

Preucil (1958) recognized the difficulties of separating ink trap from the other additivity failure factors. He coined the term "apparent trap" to characterize the degree of transfer of one ink film to another. The non-trap additivity factors are recognized by the word "apparent". Preucil's method was devised to monitor changes in ink trap, rather than to determine absolute trap.

Yule and Clapper (1956) suggested experimenting with transmission density measurements to improve the accuracy of ink trap measurements. Transmission densities are additive. The problem with this approach is that the inks are not perfectly transparent. Thus, ink A on ink B will show the same trapping as ink B on ink A even though their appearance will be quite dependent

on sequence (Field, 1983). For control purposes, it is more desirable to characterize the color of the overprint, rather than to measure trap by transmission densitometry.

Table II shows the transmission densities, and their sums, of inks printed on separate sheets of clear film. The overlap of two of these films is equal to 100% physical trap. The transmission method is inaccurate because of additivity failure attributed to the spectral response of the densitometer. The influence of the spectral response of the measuring instrument can be eliminated by measuring the sample with monochromatic light.

Table II

Additivity Behavior of 100% Trap Ink Films

<u>Inks</u>	<u>Transmission Densities</u>		
	<u>Blue</u>	<u>Green</u>	<u>Red</u>
Yellow	1.49	0.10	0.02
Magenta	0.45	1.18	0.08
Cyan	0.04	0.21	1.17
<u>Overprints and Additivity Densities</u>			
Red Overprint			
Yellow/Magenta	2.33	1.35	0.11
Yellow plus Magenta	1.94	1.28	0.10
Green Overprint			
Yellow/Cyan	1.55	0.36	1.22
Yellow plus Cyan	1.49	0.31	1.25
Blue Overprint			
Magenta/Cyan	0.49	1.38	1.27
Magenta plus Cyan	0.49	1.39	1.25

Experimental

A trapping experiment was devised that utilized the Thwing-Albert 'Quickpeek' Color Proofing Kit. Rollouts of process inks were made on a clear film substrate. The technique employed was to first roll out one ink at normal ink film thickness. In some cases the ink was allowed to dry. In other cases the second ink was applied

without waiting for the first ink to dry. The second ink was applied perpendicular to the roll-out of the first ink. The roller stroke was extended so that four repeats of the inking revolution were also transferred to the substrate (Figure 1).

If the repeat pattern of the primary inking revolution was of uniform density, then the same thickness of the second down ink was transferred to the first down ink as was transferred to the unprinted substrate. If there was a clear-cut density difference between the repeat of the area that inked the unprinted substrate and the repeat of the area that inked the first down ink film, then this density difference would indicate deviance from perfect trapping.

The actual trap values may be predicted from the density readings of the second down ink roll-out and the subsequent repeat patterns.

If D_2 is the density of the second down ink on the substrate, D_3 is the density of the first repeat of the substrate, and D_4 is the density of the first repeat of the overprint. D_5 , D_7 , D_9 and D_6 , D_8 , D_{10} are, respectively, the second, third, and fourth repeat densities of the substrate and the overprint. D_x is the unknown density of the second down ink^x over the first down ink. Hence,

$$D_2 + D_3 + D_5 + D_7 + D_9 = D_x + D_4 + D_6 + D_8 + D_{10} \quad (1)$$

or,

$$D_x = D_2 + D_3 + D_5 + D_7 + D_9 - D_4 - D_6 - D_8 - D_{10} \quad (2)$$

Fractional trap can be expressed as,

$$\text{Fractional Trap} = \frac{D_x}{D_2} \quad (3)$$

Substituting equation (2) into equation (3), we get,

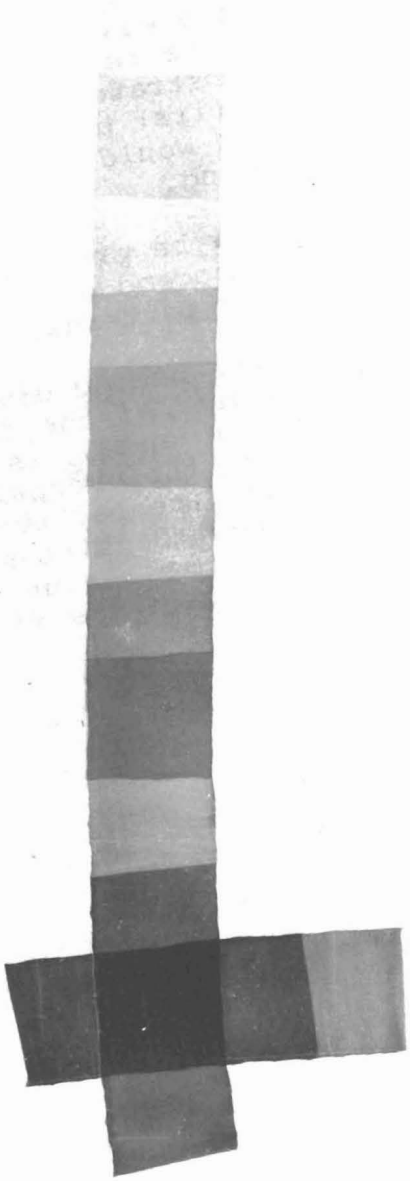


Figure 1 Rollout Repeat Patterns

$$\text{Percent Trap} = \frac{D_2 + D_3 + D_5 + D_7 + D_9 - D_4 - D_6 - D_8 - D_{10}}{D_2} \times 100$$

In order to test the validity of rollout repeat pattern trapping analysis, it was necessary to eliminate the non-trapping sources of additivity failure. This was accomplished by using transmission densitometry and making the first down ink the same as the second down ink (eg. cyan on cyan). Transmission densities of the same ink are additive, i.e. they are proportional to ink film thickness. Therefore, transmission density measurements were made of the first down ink, D_1 , the overprint, D_{op} , the second down ink, D_2 ; and the repeat patterns, D_3 to D_{10} .

The rollout pattern analysis method was used to predict D_x , the density of the second down ink over the first down ink. When D_x is added to the density of the first down ink, D_1 , the sum should equal the density of the overprint, D_{op} . The results of this experiment are presented in Table III. The difference between the overprint densities and the predicted densities is quite small. Perhaps some light scattering in the higher (slightly opaque) ink film thicknesses (especially the overprints) caused higher than expected densities for these areas.

An analysis of different color ink overlaps was then conducted. In this case it was not possible to use the transmission densitometer to measure trapping (the spectral response problem would cause inaccurate readings). Therefore, the repeat pattern method was used to derive actual trap. Transmission density measurements were used for this aspect of the study. Next, a reflection densitometer was used to measure the individual solids and overlaps in the conventional manner. The objective was to see how far apparent trap differed from actual trap for a given set of conditions. The results of this analysis are presented in Table IV. The first down ink was allowed to dry before overprinting with the second down ink, hence the reason for the 100% actual trap values by the repeat pattern method.

Table III

Repeat Pattern Trap Analysis

<u>Ink Color</u>	D ₁	D ₂	D ₃	<u>Transmission Densities</u>			D ₇	D ₈
				D ₄	D ₅	D ₆		
Yellow	1.0750	0.8000	0.3743	0.7150	0.1800	0.3418	0.0633	0.1609
Magenta	0.6141	0.4933	0.2488	0.4050	0.1167	0.1920	0.0363	0.0770
Cyan	1.0418	0.8138	0.3067	0.5708	0.1243	0.2350	0.0488	0.0990
	D ₉	D ₁₀	D _{op}					
Yellow	0.0150	0.0555	1.2638	<u>Note:</u> Density data are the averages of at least ten measurements.				
Magenta	0.0111	0.0222	0.8760					
Cyan	0.0200	0.0390	1.4400					

Results

<u>Yellow</u>	D _x	0.1594	<u>Magenta</u>	D _x	0.2100	<u>Cyan</u>	D _x	0.3698
	+ D ₁	1.0750		+ D ₁	0.6410		+ D ₁	1.0418
		<hr/>			<hr/>			<hr/>
		1.2344			0.8510			1.4116
vs. D _{op}		1.2638	vs. D _{op}		0.8760	vs. D _{op}		1.4400

Table IV

Apparent vs. Actual Trap

<u>Sequence</u>	Apparent Trap*	Actual Trap**
Cyan on Yellow	97	100
Yellow on Cyan	104	100
Magenta on Yellow	99	100
Yellow on Magenta	105	100
Cyan on Magenta	106	100
Magenta on Cyan	102	100

*Preucil formula, results expressed as a percentage

**Repeat pattern method, results expressed as a percentage

More absorptive substrates would probably produce lower relative values for the overprint densities, hence resulting in lower percent trap values. It is estimated that actual trap values of 100% will probably be recorded as apparent trap values ranging from about 92 to 100%.

Because the repeat pattern method uses transmission densitometry, the effects of first surface reflection and multiple internal reflection are eliminated. The spectral response is not a major factor because the overlaps are not measured. Opacity is not a concern because it is proportional to ink film thickness. Backtrap was not important in this experiment because the transfer was made to dry ink films or to inks of the same color. Therefore, trapping has been isolated from the other factors contributing to additivity failure. The difference between the traditional ink trap calculations and the repeat pattern calculations shown in Table IV, represent the influence of the additivity failure factors other than ink trap.

The method described here has its primary application in laboratory investigations of additivity failure factors. Plant quality control

personnel probably do not need actual trap values in order to develop effective ink trap control limits. Therefore, Preucil's concept of apparent trap would seem to be satisfactory for characterizing changes in ink trap (Jorgensen, 1983).

It is important that the same densitometer is used when making comparisons of apparent trap. Yule and Clapper (1956) reported that a yellow and magenta combination exhibited a lack of additivity when measured through a narrow band blue filter, no additivity failure when measured through a wide band blue filter, and superadditivity when measured through a cyan filter. Spectrophotometric analysis would seem to offer possibilities for controlling or predicting the spectral response aspect of additivity failure.

Ink Trap Equations

Several equations have been proposed for ink trap (or apparent ink trap) measurement. The earliest is the Preucil equation (1958), where,

$$\text{Percent Apparent Ink Trap} = \frac{D_{op} - D_1}{D_2} \times 100$$

D_{op} is the density of the overprint, D_1 is the density of the first down ink, and D_2 is the density of the second down ink. All densities for this and subsequent equations are measured through the filter complementary to the second down ink color. The symbols in the following equations have been converted from their original form to the convention shown above.

Preucil's equation was criticized because ratios of logarithms (densities) are used rather than antilogarithms when solving the equation. Childers (1980) proposed a new equation,

$$\text{Percent Trap} = 10^{(D_{op} - D_1 - D_2)} \times 100$$

Brunner (1984) has also suggested an alternate ink trap equation,

$$\text{Percent Trap} = \frac{1 - 10^{-D_{op}}}{1 - 10^{-(D_1 + D_2)}} \times 100$$

The Childers equation has been criticized by Elyjiw (1981) for producing results further away from actual trapping than those results produced by the Preucil equation.

Trapping equations may be evaluated by a method suggested by Pearson (1983). He represents the density of the second down ink over the first down ink as D'_2 , hence,

$$D_{op} = D_1 + D'_2$$

In cases of 100% ink trap, $D'_2 = D_2$. For imperfect trap, D'_2 will vary from the D_2 value of D_2 . Hence, the method for evaluating the trapping equations is to simply keep D_2 constant while varying D'_2 above and below the D_2 value of D_2 . A series of D'_2 values were generated to test the trapping equations. Table V and Figure 2 present the results of the subsequent evaluation.

Table V

Evaluation of Ink Trap Equations

Densities				Percent Trap Values		
D'_2	D_1	D_{op}	D_2	T_p	T_c	T_b
2.00	0.45	2.45	1.20	167	631	102
1.80	0.45	2.25	1.20	150	398	102
1.60	0.45	2.05	1.20	133	251	101
1.40	0.45	1.85	1.20	117	158	101
1.20	0.45	1.65	1.20	100	100	100
1.00	0.45	1.45	1.20	83	63	99
0.80	0.45	1.25	1.20	67	40	97
0.60	0.45	1.05	1.20	50	25	93
0.40	0.45	0.85	1.20	33	16	88
0.20	0.45	0.65	1.20	17	10	79
0.00	0.45	0.45	1.20	0	6	66

T_p = Trap via Preucil Equation

T_c = Trap via Childers Equation

T_b = Trap via Brunner Equation

The Preucil equation responds in a linear manner to changes in ink film thickness (equal to changes in D'_2). The Childers and Brunner equations predict the direction of trapping

change, but because of their non-linear characteristics, do not do a very good job in predicting the magnitude of the change. The Childers equation seriously overestimates overtrapping and undertrapping. The Brunner seriously underestimates overtrapping and undertrapping.

The results generated by the Childers and Brunner equations are dependent on the density of the first down ink. This is not a factor with the Preucil equation.

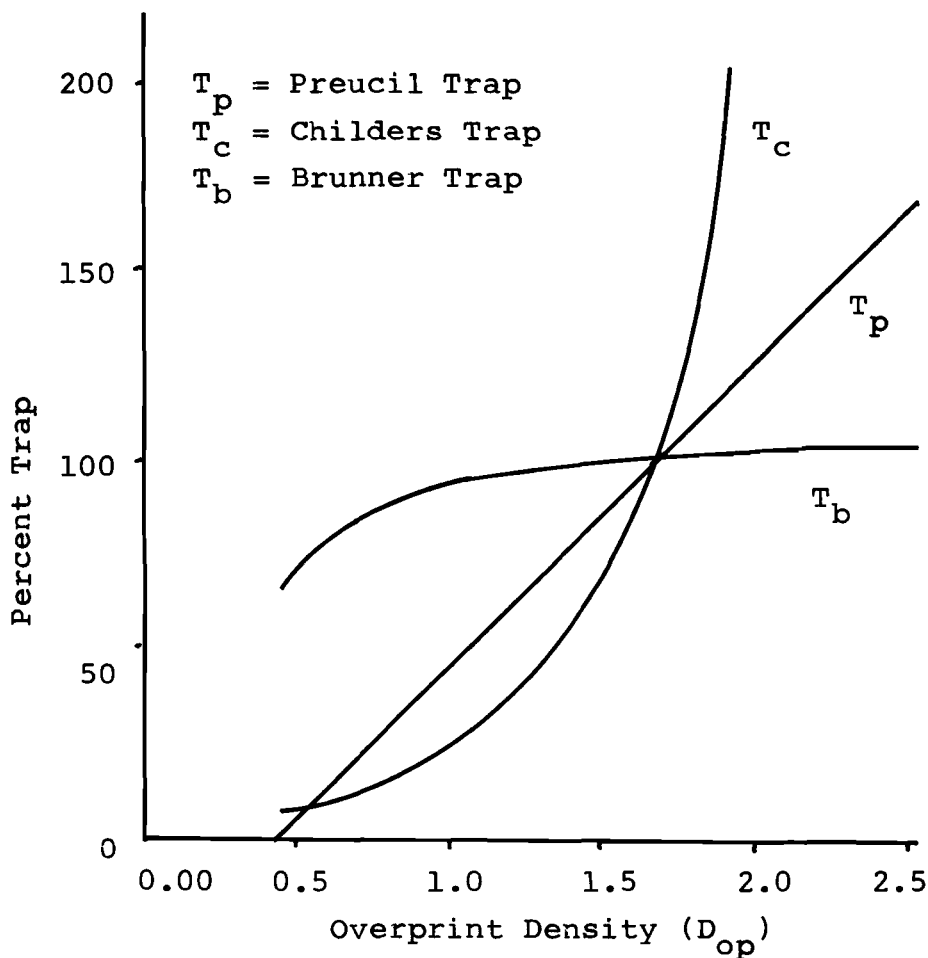


Figure 2 Evaluation of Ink Trap Equations

The mistake made by Childers and Brunner is to treat density values as logarithms (which, of course, they are) rather than as surrogate measures of ink film thickness. If the densities are thought of as microns of ink, then there are no mathematical problems with the Preucil ink trap equation.

Conclusions

Laboratory experiments utilizing repeat patterns show promise as a new method for studying and measuring ink trap. The primary value of this technique is likely to be for laboratory investigations if additivity failure factors.

Actual trap values are not required for overprint control on press, therefore, Preucil's "apparent trap" would seem to be perfectly satisfactory for process control purposes. His equation will give closer results to actual trap than either the Childers or Brunner equations.

The accuracy of optical methods of ink trap measurement are influenced by the spectral response of the instrument. Attempts to standardize densitometer response, or to use spectrophotometers to characterize overprint colors, should improve the process of ink trap measurement. Colorimeters may also prove to be useful instruments for characterizing overprint colors.

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