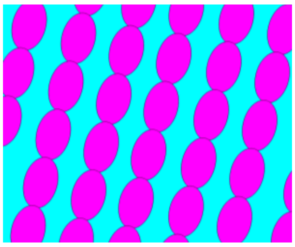
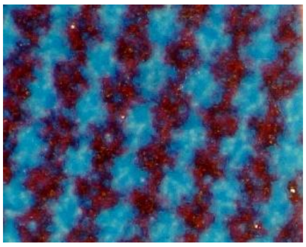
Ink trapping in offset printing

In process printing of pasty inks the upper ink layers are never trapped with the full layer thickness compared to being printed directly on paper. This narrows the printable color gamut and may cause image problems.
Technical literature and some densitometers offer three completely different formulas for calculating density measurements to trapping rates. One set of measurements leads to significantly different results than the other according to the formula chosen. In such a strange situation we ask the simple question: Is any of them correct? And if, which one is it? And if not, is there any use in one of them for printers?

The first problem is the measurement of optical density.

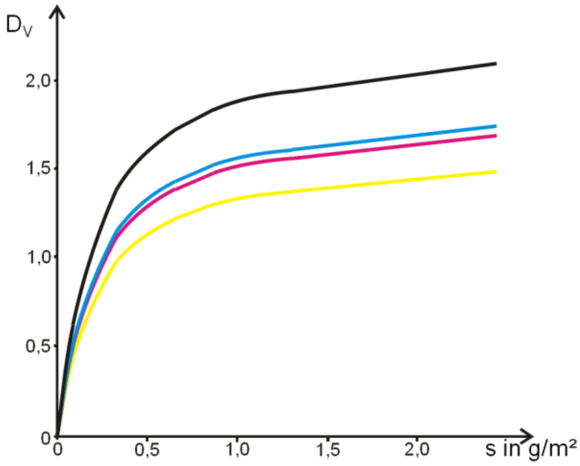
In industrial printing there is no direct way to quantify ink film thickness. So we use the optical density as a measure. It is not an exact measurement, because the basic condition is not exactly correct: It sees a printed element as a flat plate of even thickness.





Theoretically uniformly thick ink layers seen closer show to be pearly and pitted.

In a similar way our eyes function when looking on picture prints. They take a means of all small points and ink droplets, as long as they are fine enough. So fortunately the density measurement is sufficient as a means to control the offset press.



Ink film thickness against optical density of solid areas D_V

In a diagram ink layer thickness against optical density the density first rises in an approximately linear way. Then the increase weakens to end in a kind of saturation value with very high thickness values. Here we see the second imperfection in our system: If a piece of ink layer comes upon another piece, the lower affects the exact determination of the one above. And this is valid even for two layers of the same ink.

We have to face the fact that measuring two different ink layers in superposition neither the lower nor the upper is found exactly by optical density, for instance with magenta upon cyan.

Any better measurements?

If optical density has so many inaccuracies, does another technique, e. g. colorimetry, work better?
There have been several tries to find out. Sometimes the results seem convincing. And it sounds good because the registered color shade should give exactly the result, which the eye registers.
Unfortunately spectral photometers (and our eyes) gather the influence of the print and that of the printed material, too. And the material, often paper, has such a strong influence that we must not ignore it. To determine only the influence of the print we should prepare controlled ink thickness samples of different thicknesses on each paper we use. At least we should do it on a choice of typical papers. Unfortunately we cannot simply measure the unprinted paper and subtract its color coordinates from those of the print. Besides paper color also topography and absorption properties do influence the print.
Here we have the strong advantage of densitometry in printing practice: With simple measurements the paper influence is eliminated. It determines only the effect of the process colors, as long as they are standard inks (ISO 2846-1).

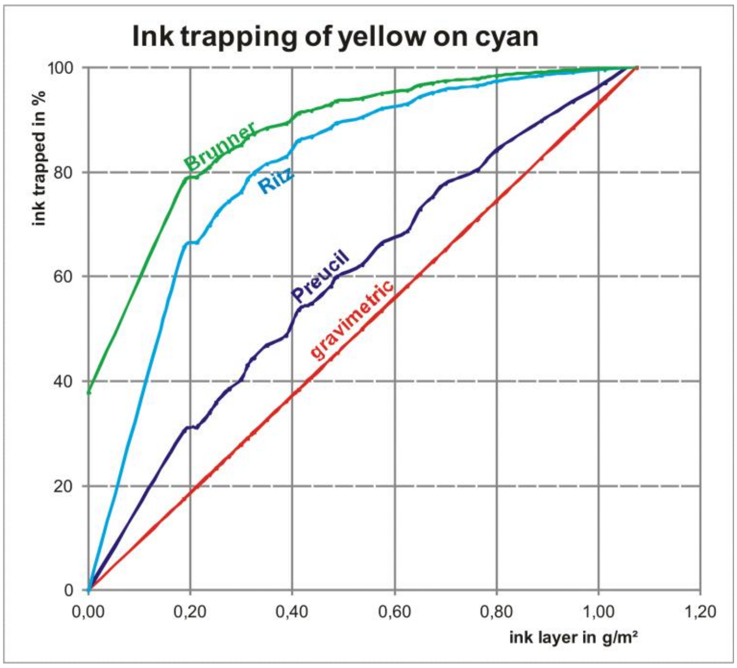
looking for a decision maker

As now we have doubts about the exactness of optical measurements, we need a controlled comparison. To determine ink quantity directly is possible - again with some limitations - gravimetrically by weighted lab prints.
On a lab printer (IGT, Prüfbau etc) a paper sheet of known area is printed from a print roller in letterpress technique. The roller is weighted exactly before and after printing. Thus we can say exactly, how much ink was transferred. What we do not know is, if the print is very pearly or very even. We only can take the average over the total area, in this case 40 x 200 mm by measuring a number of single spots. On one hand we know that a very pearly print shows slightly different color coordinates and optical density than a much smooth one. On the other hand we can prepare prints as smooth as possible with no clearly visibleclouding.
For a complete test series we have to do lab prints with ink film thicknesses stepwise from 0.2 to 1.3 g/m². Of each step we make a complete set to print then the second ink in graded weights. This gives us a complete overlook, and we can measure densitometrically and colorimetrically. Now we can compare the three calculating models for ink trapping.

Preucil, Ritz or Brunner, a comparison

Cyan and Yellow were printed on machine coated paper. The diagram shows the yellow ink films in g/m² on the x axis. On the y-axis we see the trapped ink in %. In our press prints the solid areas of yellow correspond to lab prints with 1.08 g/m². The same ink thickness upon cyan thus would correspond to 100 % of trapping.
Following Preucil´s formula, the calculations gave up to 15% higher values compared to gravimetry and end with 100 %. Other couples also showed phases with lower results and ended below 100 %.

If we have a look on the other formulas, we must expect different curves for Ritz and Brunner. Indeed both of them give much higher results. The lowest measured ink layer (0.2 g/m², below 20 %) starts with values of 60 to 80 %. This is due to the logarithmical background of area coverage seen from absorption (see basics). But there is a clear disadvantage: They use as a gamut of differentiation only the upper third of the percent range. They react with limited sensitivity. And by the way they use rather complicated mathematics.



The graph ink layer versus trapping shows how differently the three calculation models see the truth.

What can we tell the printers?

In the press room ink trapping is a problem we are looking for rather late. Usually in four color printing first we control the optical densities of the solids and dot gain, if somebody is not satisfied with the printed colors. If they are within the standard, and still there is too much difference in certain picture areas, it is worthwhile to estimate the ink trapping. Practical experience tells us that too low trapping becomes visible with 10 % or more. So a very precise measurement is not really what we are looking for. This tells us that each of the three formulas help in some way. Why then use a complicated formula with poor differentiation instead of the simple model of Preucil. And this is what printers do, they only use Preucil.

Generally the simple formula is set as default in densitometers, and nobody cares. Ritz and Brunner formulas are intended for very special applications. They should have named with extra expressions to avoid mix-up and confusion. Ritz called his item “pearl factor” and thus helps not to mix up with ink trapping. But in literature they are usually treated as three ways to get the same goal.

The author thanks André Strunk and Fabian Junge, former students of print and media technology at Wuppertal University for numerous lab data, which made this survey possible.

---------------------------------- Some basics ---

Three quite different formulas: What do they tell us?

In literature, brochures and densitometers we find the formulas of Preucil, Ritz and Brunner for the calculation of ink trapping. Preucil uses optical density as a means for ink film thickness. Ritz and Brunner use fictitious tone values, that´s area percentages of ink covering. This cannot be the same, because tonal value goes with the light absorption, whereas optical density is a logarithm of it.
By the way, the most frequent mistake in practice: We must not always use only the primary densities (measured with the filter of the intended color). Here the secondary densities are the reasons of measuring errors. Advice: Always take the filter of the upper color, because it has the problem (D_2 and D_{12}) - also for the solids of the first color (D_1). The color below is complete and does not need calculations.

Following **Preucil** we simplify ink layers as thin plates positioned one above the other. The thickness of the upper ink in relation to a layer on paper given in percent is defined as “ink trapping FA”. As the formula is simple, it is the mostly used.

$$FA_P = \frac{D_{12} - D_1}{D_2} \bullet 100\%$$

Ritz considers the upper ink layer as pearly distributed (pearl factor). He treats it as a screen laying on top of the plate formed lower ink. With complete trapping this results in 100 % in a kind of area coverage, below in correspondence lower. Using measurements of the optical density, Ritz does not use really area coverage, but tonal value, on paper slightly higher values (light trap).

$$FA_R = \frac{1 - 10^{-(D_{12} - D_1)}}{1 - 10^{-D_2}} \bullet 100\%$$

The **Brunner system** also uses densitometric measurements, at least in the formulas implemented in densitometers. It calculates a very special version of tonal values. In a formula based on Murray-Davies the density of the double print D_{12} is compared with a theoretical sum of the densities of both colors, printed as single solids on paper ($D_1 + D_2$).

$$FA_B = \frac{1 - 10^{-D_{12}}}{1 - 10^{-(D_1 + D_2)}} \bullet 100\%$$

Bergheim, 21st June, 2012