Benefits of Concentric Screening in Offset Lithography

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Keywords

Concentric	Concentric Screening
Screening	Halftone
Stochastic	Stochastic Screening
Offset Printing	

Abstract

Concentric Screening™ is a halftone screening technology in which the large solid halftone dot is divided into thin "concentric" rings. The thin rings limit the ink film thickness on the offset plate. The result is a halftone dot which prints with less variation on press, exhibits higher color saturation, enables printers to go to much higher screen rulings, and consumes 15% to 30% less ink than normal AM screening. While stochastic screening has shown many benefits on press in recent years, it suffers from one major problem: a grainy appearance. It is a fact of the human visual system that a uniform pattern appears smoother to the eye than a random pattern. A stochastic screen is a small spot that is randomly distributed. The benefits of stochastic screening are related to the small spot size, not the random distribution. By dividing the large AM halftone dot into thin concentric rings, the Concentric Screen has similar on press benefits as the stochastic screen. Because the pattern in uniformly arranged, the screens appear smoother than stochastic screens.

The benefits of Concentric Screens can be confirmed quantitatively by running two simple tests – both consisting of an AM vignette from 0% to 100% printed side by side with a Concentric vignette. By measuring the LCH values throughout the vignettes on the same sheet and plotting the relationship between Chroma and Lightness of each screen, it can be determined which screen produce higher chroma and, by deduction, thinner ink films. By printing the same sheet at different ink levels (e.g. low density and high density) the degree of stability on press can be measured. These results of these tests, described in this paper, show that Concentric Screens are superior to AM screens.

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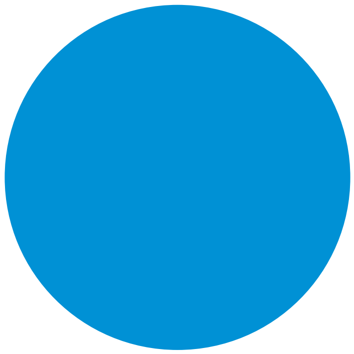


Figure 1a
Normal Halftone Dot

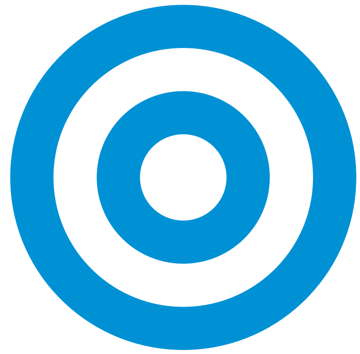


Figure 1b
Concentric Halftone Dot

The function of the Concentric Screen is to provide the benefits of stochastic screening without the grainy appearance. A stochastic screen is a small spot which is randomly distributed. The benefits of stochastic screening are related to the small spot size - not the random distribution. The random distribution results in a grainy appearance. As seen in figure 2, the smoothest screen is the uniformly spaced AM screen.

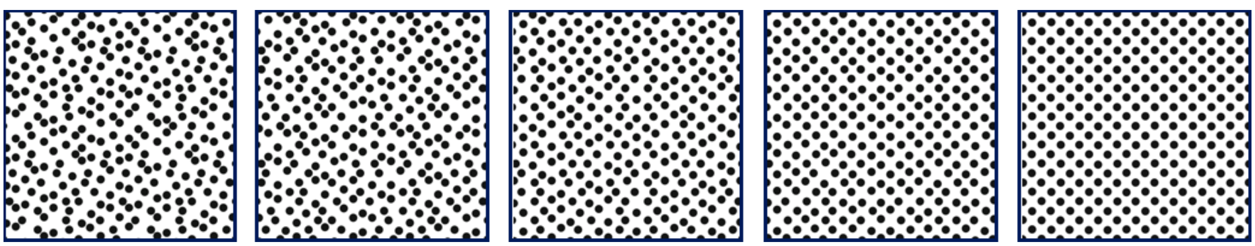


Figure 2 - Screen smoothness varies inversely with randomness.

With AM screens, dot size increases with grey level. Large dots carry thick films of ink. By dividing the large AM dot into smaller rings, the press benefits of stochastic screening can be achieved - but with the smoothness of AM. The difference is visible to the eye and measurable on the printed sheet.

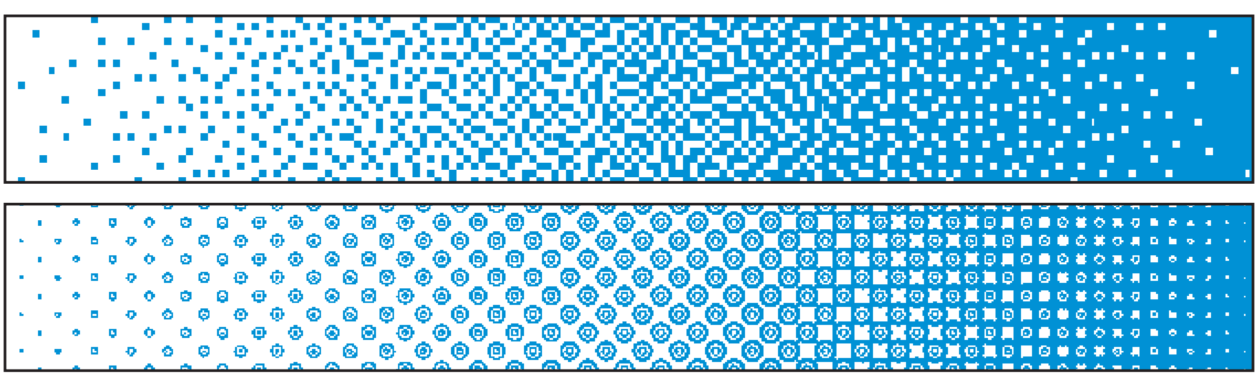


Figure 3a - Stochastic Screen (top) Figure 3b - Concentric Screen (bottom)

The "work" of the Concentric Screen occurs on the offset plate. According to the principles of fluid mechanics, ink film thickness is proportional to the size of the image element on the plate. While a 100μ element (50% AM dot) might carry 10μ of ink, a 20μ element (20μ FM spot or 20μ Concentric Ring) might carry only 2μ of ink. The result is lower ink consumption and greater color saturation. Additionally, when ink volume increases on press due to natural variation, the 20μ element is already carrying its capacity, accepts no more ink, and therefore has less variation on press.

The illustrations in Figure 4 show how both the Concentric Dot and the Stochastic Dot carry less ink on an offset plate than a solid AM dot. To be more specific, with light ink coverage (fig 4a) all dots carry the same ink film thickness and there is no real "ink limiting" benefit of a Concentric or stochastic screen. However, as ink volume is increased to achieve densities in the normal print density range, the ink film thickness on the AM dot continues to increase while the ink film thickness on the Concentric and Stochastic Dot remains the same.

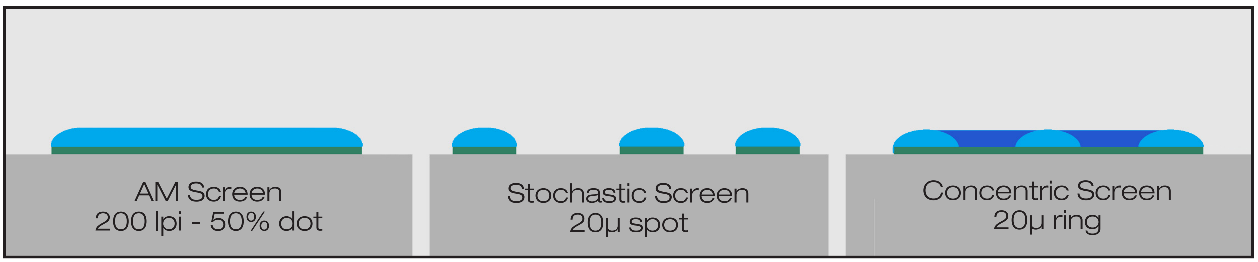


Figure 4a - Cross Section - Ink Film Thickness on Offset Plate - Light Ink

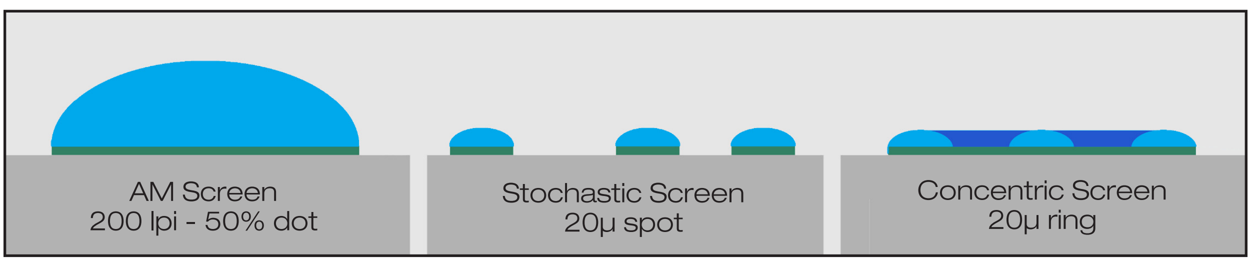


Figure 4b - Cross Section - Ink Film Thickness on Offset Plate - Heavy Ink

Greater Press Stability - Press Stability can be tested by running two screens side by side and asking the pressman to intentionally change printing conditions (e.g.. increase and decrease ink). The results can be measured on the printed sheet. The screen that changes least has the greatest press stability. Concentric has been shown in independent research to have greater stability than normal AM and equal or greater stability than stochastic. Additionally, unlike stochastic which has "fixed stability" (based on spot size), Concentric Screening offers "user-adjustable" stability. A user can decrease ring width for greater press stability or increase ring width for less press stability (greater press "adjustability").

Less Visibility - A Concentric Screen is less visible to the human eye than an AM screen of the same ruling. Thin ink films produce lighter inks. Larger dots printed with light ink are less visible than smaller dots printed with dark ink. The effect can be seen by comparing the car interiors in article A. The 170 lpi Concentric Screen (top right car interior) is significantly less visible than the 170 lpi Normal AM screen (top left car interior).

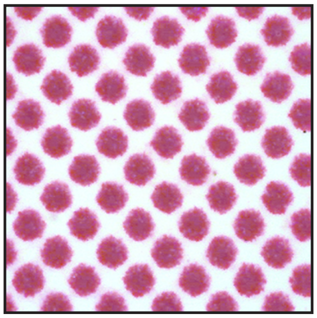


Figure 5a
175lpi AM Screen

Figure 5b
175lpi Concentric Screen

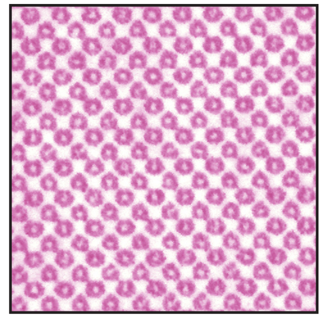


Figure 5c
310lpi Concentric Screen

Higher Screen Rulings - Printers typically increase screen ruling by a factor of 1.5x to 2x when changing from normal AM to Concentric. Sheetfed printers have moved to 300 lpi and higher while web printers are now at 200 lpi and climbing. The higher ruling capability can be measured in test sheets by using press stability analysis (described above). It is consistently observed that high ruling Concentric screens have similar or greater press stability than low ruling AM..

Higher Chroma - Concentric Screens produce higher chroma than normal halftone screens. The increase in chroma can be measured in a vignette from about 5%, where the dots begin to form rings, to about 95% where the dots become solid (figure 6 - below). This range is greater than that of stochastic screens. The effect has also been measured using micro spectrophotometry by independent researchers and can be seen in the photomicrographs in figure 5a. The images in figure 5a show that higher chroma is achieved even at low rulings (e.g. 175 lpi) and that with Concentric Screening, chroma is ruling-independent

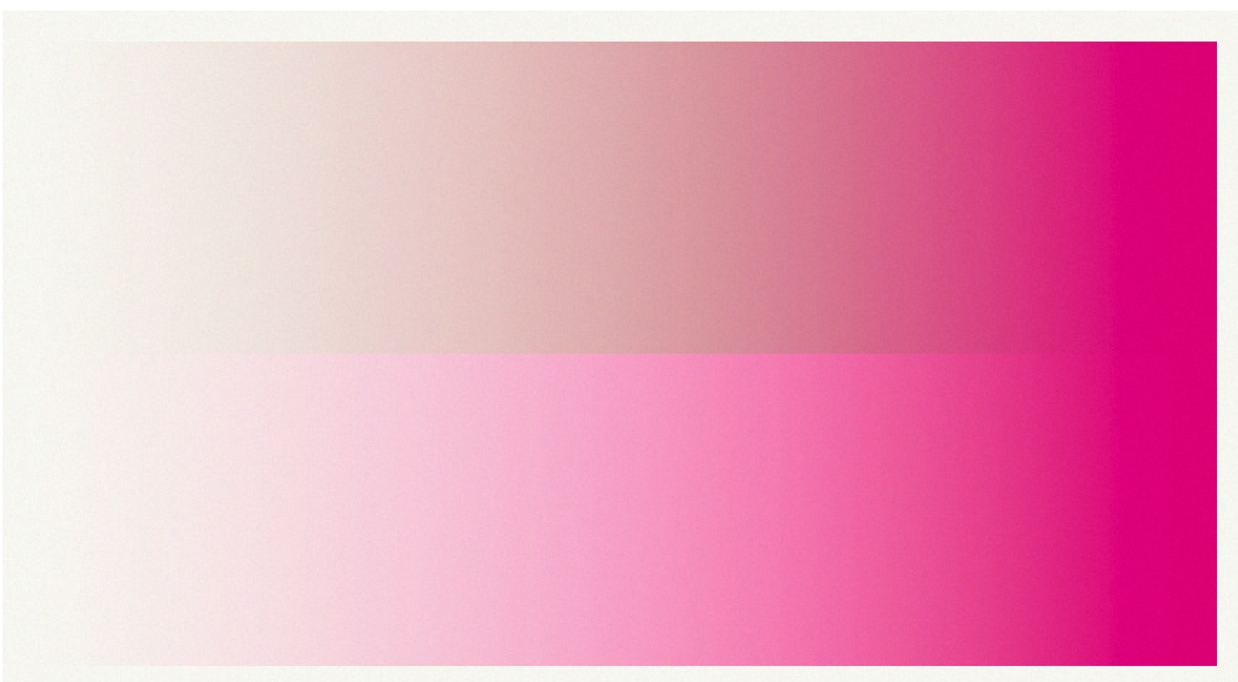


Figure 6 - 175lpi AM Screen (top); 175lpi Concentric Screen (bottom)

Quantitative Evidence

The benefits of Concentric screening described to this point in the paper can be clearly observed on the printed sheet. The most valid comparison can be made by printing and AM or stochastic screen next to the Concentric Screen. These benefits can also be confirmed scientifically with quantitative evidence. Fortunately, the analysis is simple, yet robust.

The Chroma Effect

To support for the "hypothesis" that Concentric Screens produce higher chroma colors, and therefore greater gamut, than AM screens, the basic objective is print and measure an AM screen and a Concentric Screen next to each other on the same sheet. Through measurement of Chroma (C of CIE LCH), it can be determined which screen produced the highest chroma. There is one concept to consider, however, to avoid being mislead: for a printed single color of ink: the highest chroma is always at the darkest tint value. This is usually the 100% value - the solid. Since the 100% of a Concentric Screen is the same as any other screen (which is a solid), such a comparison will yield no information. We need to compare screen tints, not solids. Here too, a simple single measurement can be misleading. In most cases, a Concentric Screen will have more dot gain than an AM screen. A 50% Concentric dot on plate will produce a darker color (lower L of CIE LAB) than a 50% AM dot on plate will produce. A darker color will always have a higher chroma. Therefore, simply measuring the same patch on the grey scale a making a direct comparison is not enough to conclude one screen produced higher chroma colors than another screen. To make a valid comparison, we might compare colors of the same Lightness value (L of CIELAB). This has been done on over a hundred press sheets to date and there has not been a single case where the Concentric Screen did not have a higher Chroma than the AM screen when comparing two tints of the same Lightness value.

A more thorough and revealing way to remove the Lightness effect from the Chroma effect is to plot a graph of Chroma vs Lightness for both the AM and the Concentric Screen. While curve adjustments in prepress can be used to make a color lighter or darker, the only known way to produce higher chroma at a given level of lightness (without changing ink) is to print a thinner film of ink. Below is are Chroma vs Lightness curves for AM and Concentric Screens (Figure 7).

These curves are shown for two different ink film thicknesses. The top illustration represents a "normal" Cyan ink density of about 1.5 (close to the GRACoL spec). The bottom illustration represents a "low" Cyan ink density of about 1.2 (lower than any spec for coated paper). Notice that the samples with the higher ink densities showed the Concentric effect to a greater extent. With normal densities the Concentric Screen produced a Chroma of about 4 units higher throughout most of the scale than the AM screen produced. This is about 13% higher in chroma at a midtone chroma level of 30 (13/30 = 13%) and is visibly noticeable to the eye to large degree.

Notice that the samples with the lower ink densities still showed the Chroma effect, but to a lesser extent than the sample with the higher ink densities. With low ink densities the Concentric Screen produced a Chroma of about 2 units higher throughout most of the scale than the AM screen produced. This is about 6% higher in chroma at a midtone chroma level of 30 (6/30 = 6%). Such a difference is still visibly noticeable to the eye to fairly large degree.

Not shown here, is the observed finding that when printed to an extremely low density (e.g. below 0.8 for coated stock), the Chroma vs Lightness curves for Concentric and AM are the same. At this low density, neither the AM nor the Concentric dot has reached its maximum ink carrying capacity. Both carry the same ink film thickness and produce the same chroma.

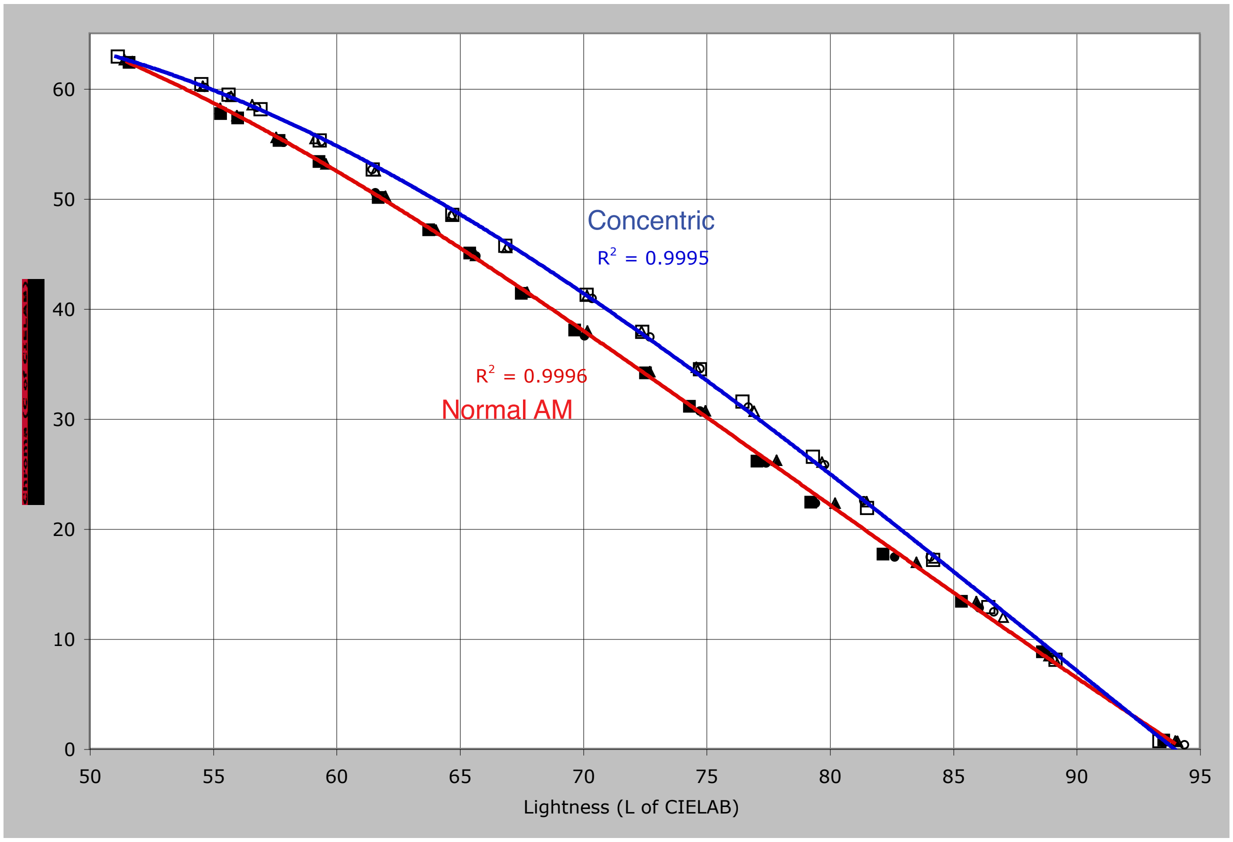
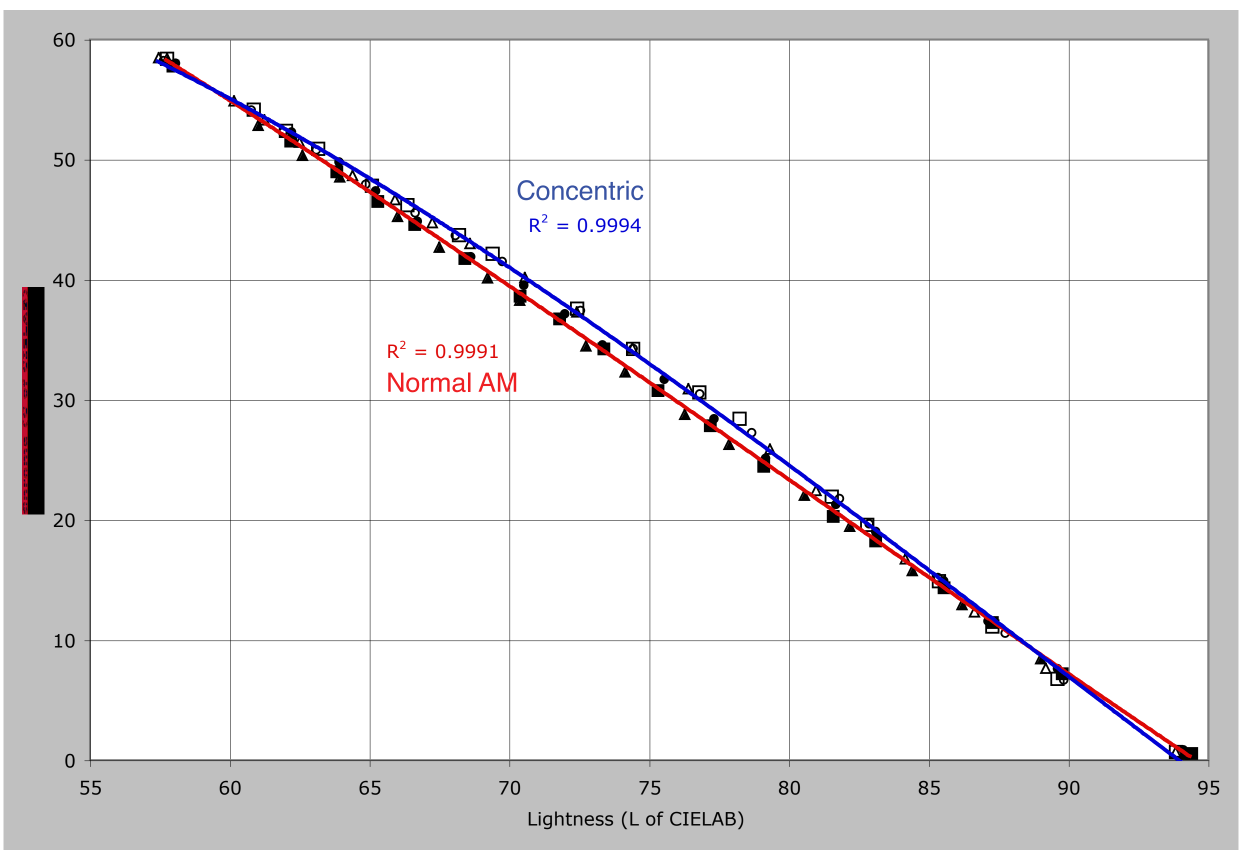
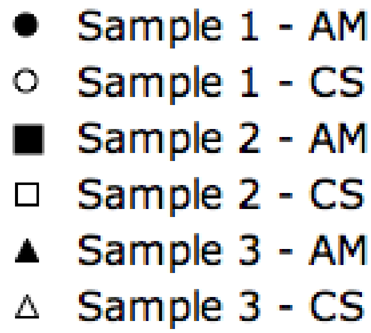


Figure 7 - Chroma Effect - Concentric vs AM Normal Ink Density (top); Light Ink Density (bottom)



Technical Description of Curves

The above "Chroma Curves" and the below "Press Stability Curves" were both plotted from 3 separate press sheets randomly selected from the same press run. The AM samples are shown with solid markers (round, square, and triangle) the Concentric Screens are shown with hollow markers. The curves are plotted to the complete set of data based on the observation that the "between treatment" variation is many time greater than the "within treatment" variation.



Quantitative Evidence of Press Stability

While the ink film thickness effect "implies" greater press stability, the only way to truly prove press stability is to print a Concentric and an AM screen side by side, vary the ink applied to the plate and see which screen changes by a greater amount. We could plot normal dot gain curves - comparing some metric (density, dot area, L of CIE LAB) on the printed sheet to the value on the digital file or plate. A more revealing approach is to plot "ΔE above paper" of the low density sheet vs "ΔE above paper" of the high density sheet for both the AM and the Concentric Screens. With such an approach, if increasing ink has no effect on color (LAB values), the result would be a straight line (the black line in figure 8). The distance from the straight line indicates the degree of sensitivity of the screen to changing press conditions. Notice that the Concentric Screen is far less sensitive to changing press conditions than the normal AM screen. With the Concentric, there is almost no change from the highlight through the midtone. It does get darker as would be expected (and arguably desired) as it moves toward the shadow. At 100% (the solid) the AM and Concentric Screens are the same as would be expected (a solid is a solid).

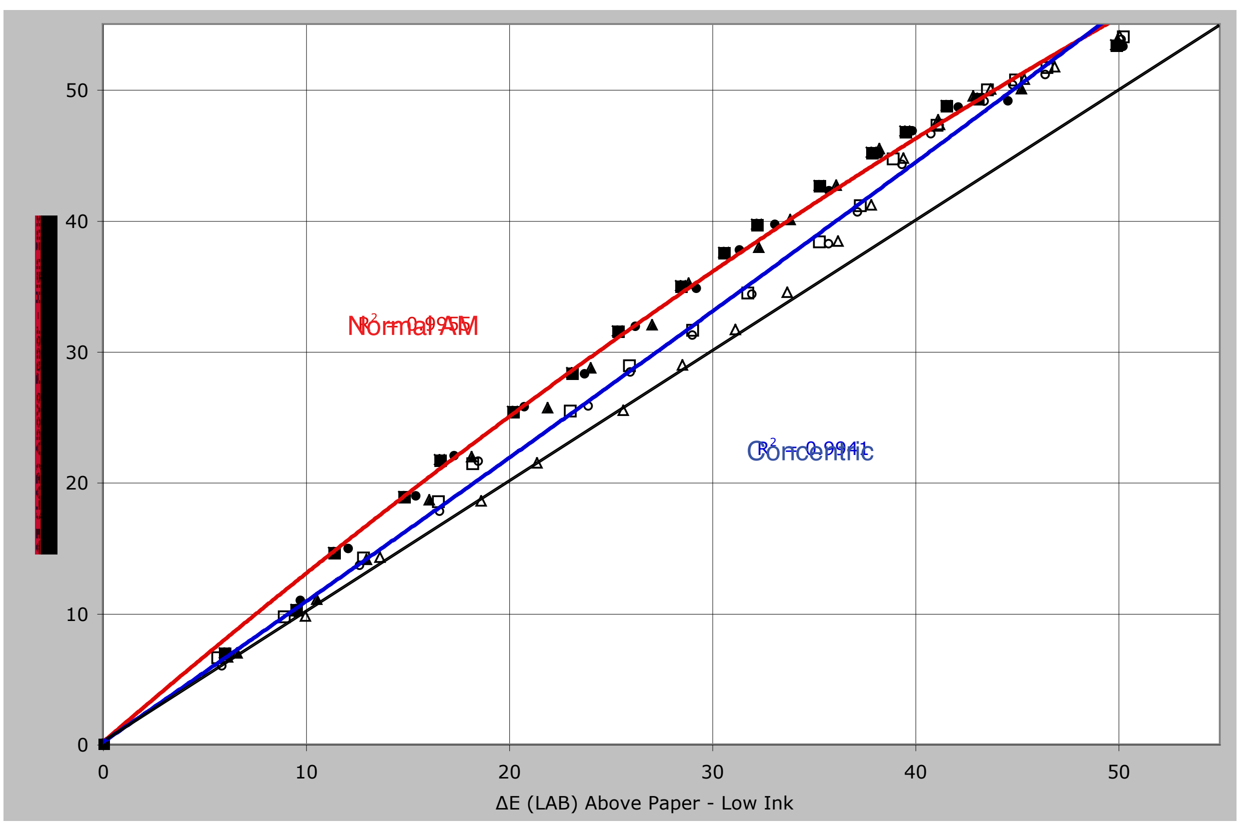


Figure 8 - Press Stability - Concentric vs AM