# Measuring TVI of a spot color[1]

John Seymour, Feb 18, 2013

### Summary

The calculation of TVI for standard process colors (CMYK) is long established and standardized. TVI is based on a formula, the Murray-Davies formula, which was introduced in 1936. The spectral filters to be used to calculate reflectance have long been standardized as either Status T or E. The most recent version of ISO 12647-1 (the key standard for all print) has made a minor revision to the calculation of TVI based on colorimetric values, XYZ.

There has been no such standardization for spot colors (i.e. Pantone inks). In some cases one could readily choose one of the standard Status filters – for some inks, the choice would be unambiguous and presumably would work well. There are other inks where there are two reasonable choices. For example, red ink has high density in both the blue and green channels. Green ink is perhaps a bit more perplexing in that the channels of high density are at opposite ends of the spectrum. There has been no standardized recommendation for which channel to use for each of the Pantone inks. It is also not clear whether each ink has a filter that would "work well".

One de facto standard for filter selection has been to analyze the spectrum of the solid, and choose the wavelength of highest density, that is, lowest reflectance. For convenience, I will refer to this as $\text{TVI}_{\text{mw}}$. Often, this works well, but as we shall see, this technique will give terribly misleading results for many inks.

### A quick look at TVI curves

For this study, I investigated spectral data on tone ramps of 394 different inks. Figure 1 shows a random selection of the $\text{TVI}_{\text{wm}}$ curves from this set of spot colors. For the most part, the $\text{TVI}_{\text{mw}}$ values were quite large, and in some cases, astronomical. This data is gravure, so a typical TVI for a CMYK ink is around 18% for the 50%. Of all the inks in this study, almost 90% of them (353 of the 394) had 50% $\text{TVI}_{\text{mw}}$ that were above this target.

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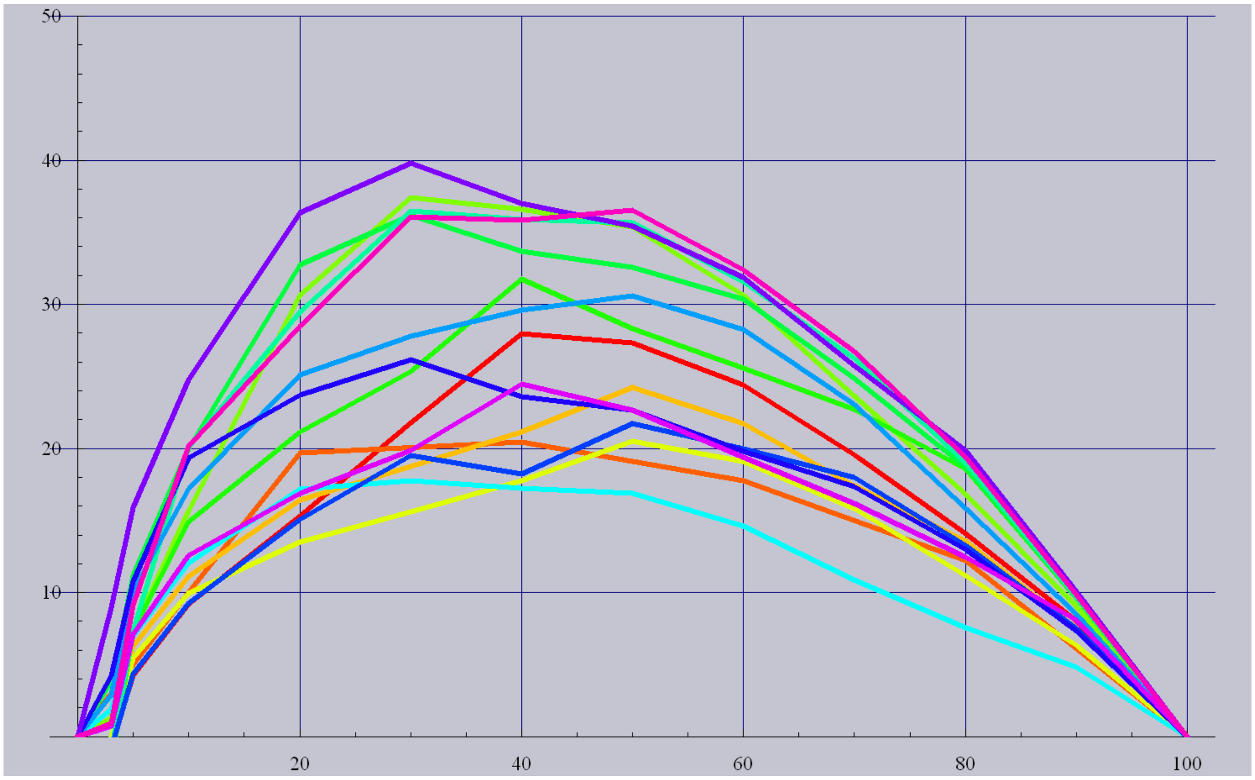

*Figure 1 - TVI$_{mw}$ curves of 15 randomly selected inks*

The shapes of these curves in Figure 1 are all reasonable, but the magnitudes of some are ridiculous. One of the inks (not shown in Figure 1) had a 50% TVI$_{mw}$ of 48.6%, in other words, according to this measure, the 50% patch looks like a 98.6%. It would be an understatement to call this plugging.

This one ink is not an anomaly. Figure 2 is a histogram showing 50% TVI$_{mw}$ of all of the inks. There were 70 inks that had a 50% TVI$_{mw}$ above 35%. I have not asked lately, but I am guessing that most prepress folks would balk if I requested plate curves that brought this down to 18%. Banding will be an issue.

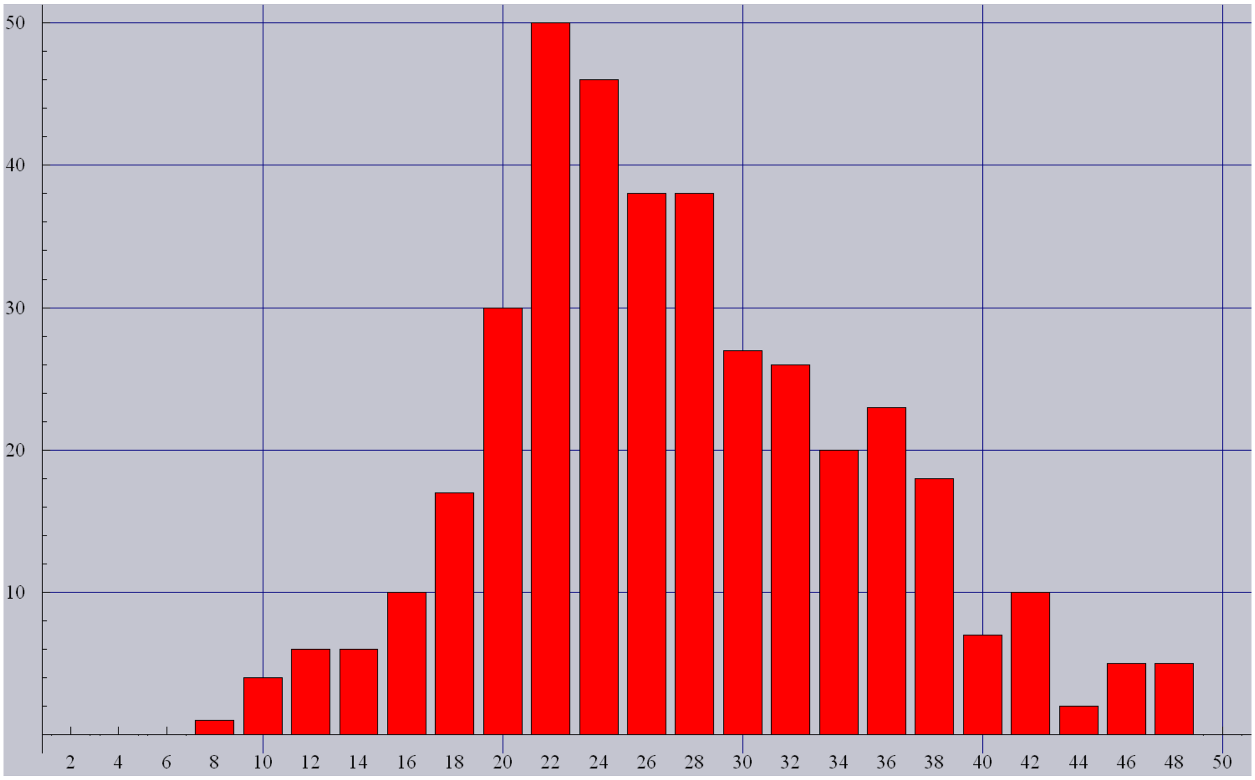

*Figure 2 – Range of* $TVI_{mw}$ *values for spot color inks*

**Bad inks? Or bad method?**

Just based on the excessive TVI values, one might be tempted to say that the inks just aren't running right. They have way too much dot gain. To check this, I arbitrarily took a closer look at the ink with $TVI_{mw}$ closest to 35%. This ink has a moderately large TVImw for the set of inks, but it is not unrepresentative. Based on the $TVI_{mw}$, it appears that there is severe plugging.

This ink happens to be blue. Figure 3 shows the $TVI_{mw}$ curve for this blue ink. The peak occurs at 30%. It would appear from this curve that the 30% halftone looks like a 70%. (There is a bit of an anomaly in the 3% halftone, which has a negative $TVI_{mw}$. This is not unusual. It just indicates that the press is unable to hold a 3% dot. Note that there is no problem holding a 5%.)

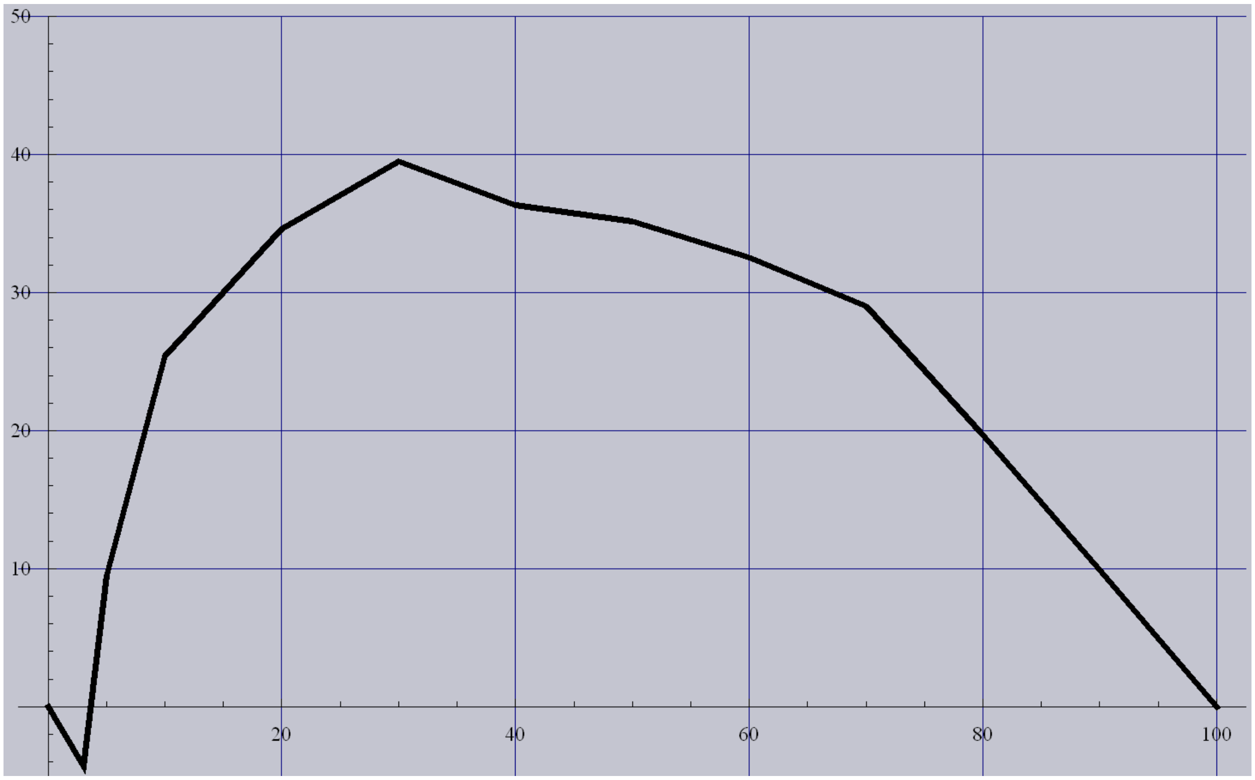

*Figure 3 – TVI$_{mw}$ curve for a blue ink with moderately high TVI*

In Figure 4, we see the spectra of the halftones, with 3%, 5%, 10%, 20%... 90%, and solid plotted. The TVI$_{mw}$ was calculated at 600 nm. In this part of the spectrum, the 70%, 80%, 90%, and solid are nearly indistinguishable. This is consistent with the TVI$_{mw}$ curve shown in Figure 3, where the 70% halftone has a TVI$_{mw}$ of very nearly 30%.

At 450 nm (at the blue end) the spectra have a very respectable fan-out. Each of the steps in the halftone ramp is easily distinguished. It would appear that we are not looking at the right wavelength to assess TVI! Or perhaps there is another approach?

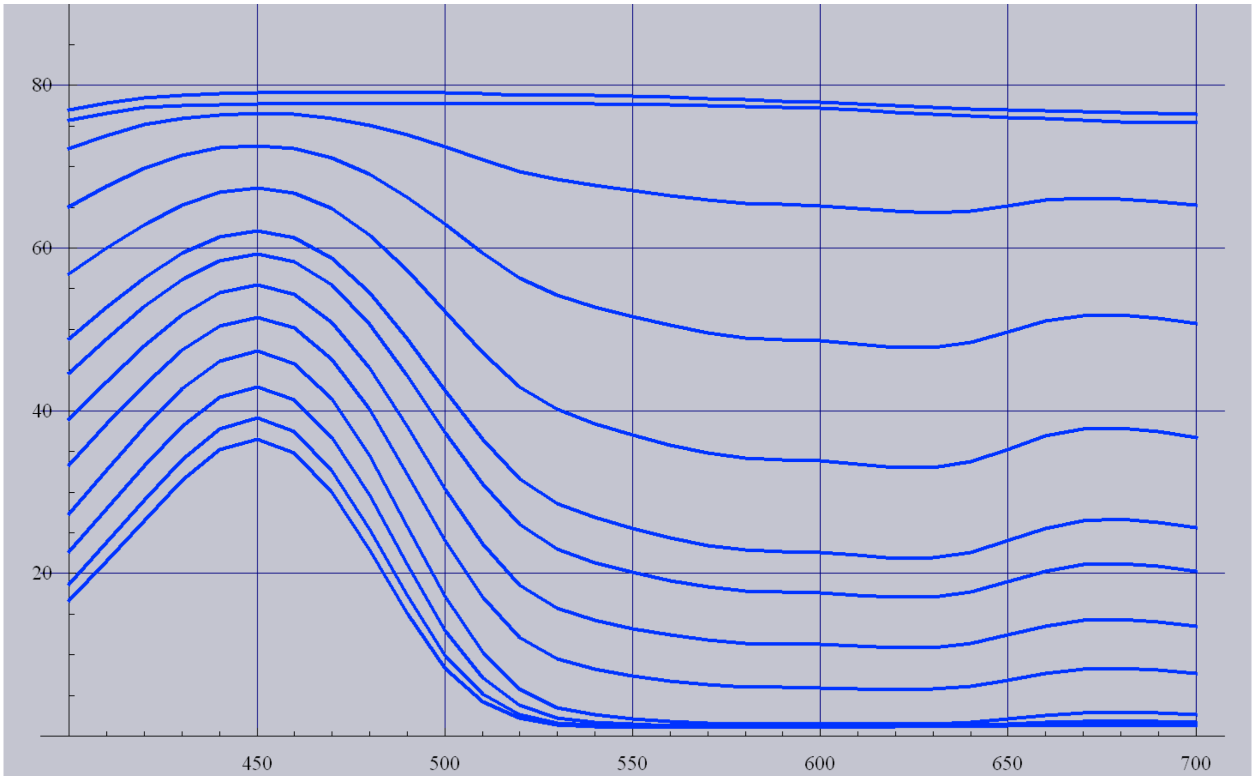

*Figure 4 – Spectra of tone curves for a blue ink with* $TVI_{mw}$ *of 35%*

## A different view of the blues

For a different view of the tone ramp, we look at the same data in CIELAB space. Figure 5 shows the tone ramp from above, that is, in an a*b* plot. Figure 6 shows a side view (L*b*) of this same tone ramp trajectory. The 70%, 80%, 90% and solid are somewhat squished together, which is evidence of high TVI. They are, however quite clearly distinct. Therefore, the extreme TVI that was diagnosed with the $TVI_{mw}$ is not real.

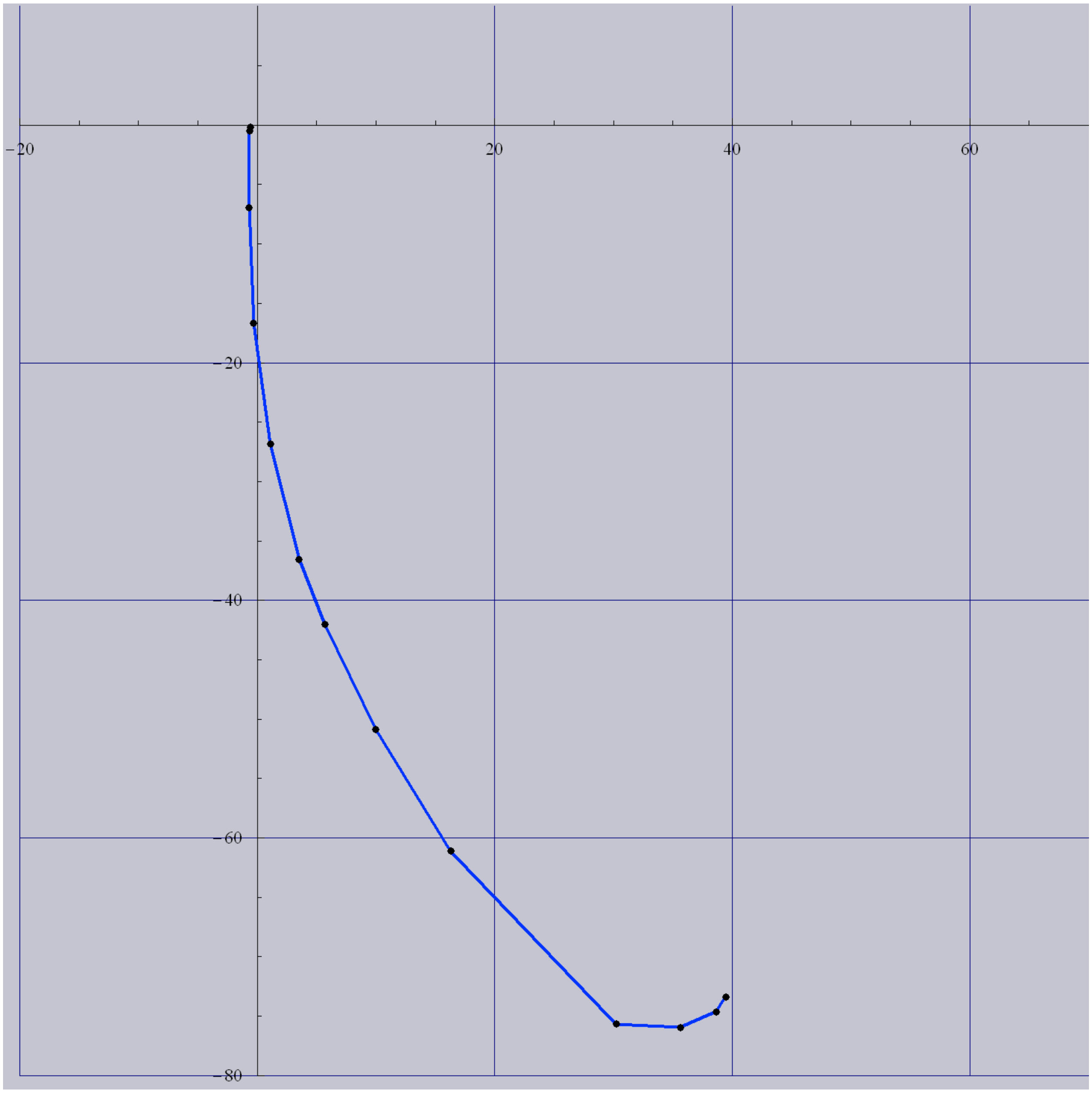

*Figure 5 – a*b* plot of the blue tone ramp*

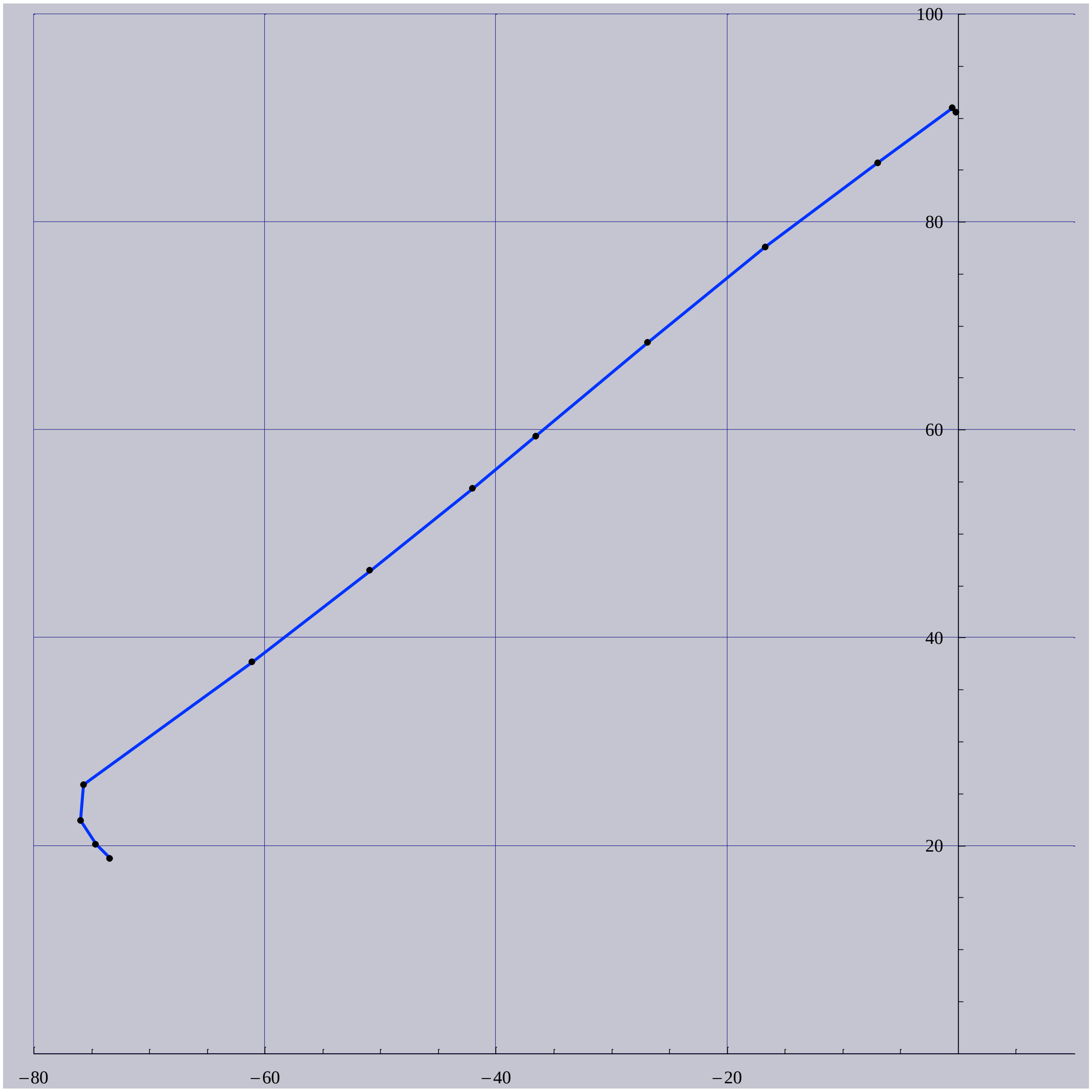

*Figure 6 – L*b* view of the blue tone ramp*

### Let’s try an orange

One odd thing about the plots in Figure 5 and 6 is that the ink has a rather strong hook. After the 70% patch, there is a sharp shift in hue toward violet. Although the tone ramp *does* get darker (the L* values continue to drop) the chroma (richness of color) does not increase. Is there a correlation between this hook effect and extreme $TVI_{wm}$ values?

There was an orange ink that exhibited an almost identical $TVI_{mv}$ value to the blue (also very close to 35%). The spectral of the tone ramps for this orange ink are shown in Figure 7, and the a*b* plot of the tone ramps for this ink are shown in Figure 8.

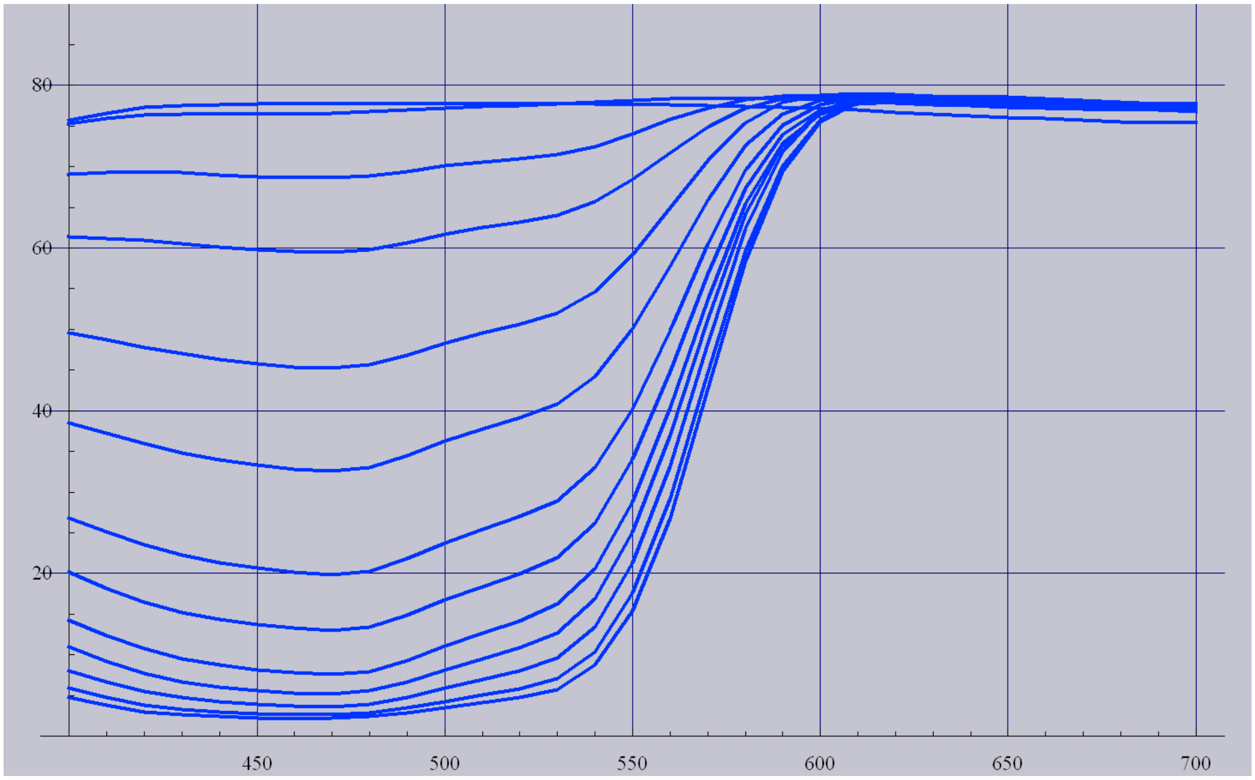

*Figure 7 – Spectra of tone curves for an orange ink with* $TVI_{mw}$ *of 35.3%*

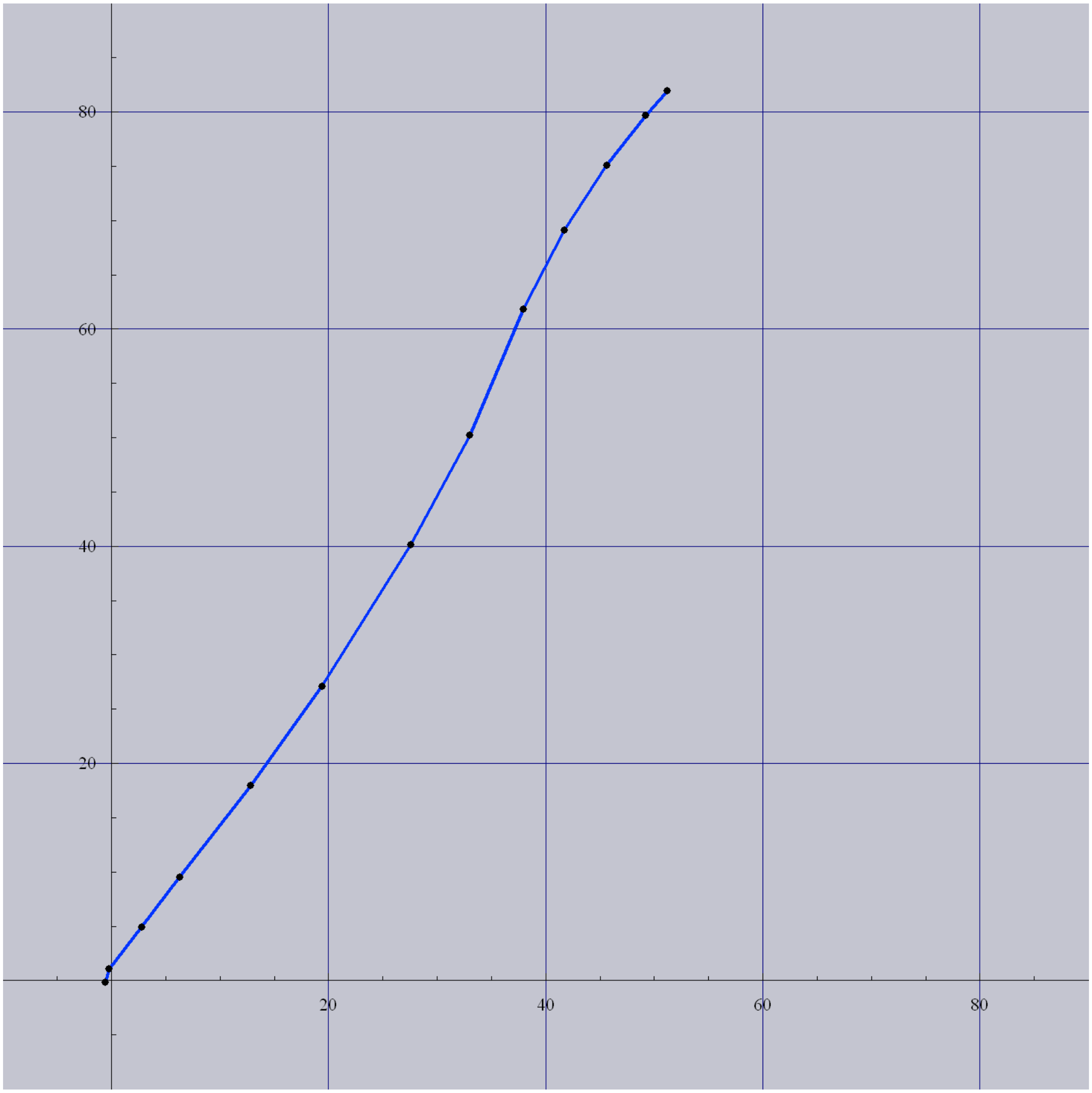

*Figure 8 – a*b* plot for an orange tone ramp*

This particular tone ramp shows virtually no hue shift. This is a direct result of the fact that the spectra, by and large, has two different reflectance values, with a sharp transition between. The reasons for this have been explained in the blog post "Why does my cyan have the blues?":

http://johnthemathguy.blogspot.com/2012/09/why-does-my-cyan-have-blues.html

It can also be seen that there is a very nice spread in the shadows for this orange ink. Very clearly the extreme value of $TVI_{mw}$ is in no way indicative of the behavior of this ink in practice. Based on a TVImw of 35%, one would conclude that the ink has no business being halftoned. Based on the a*b* plot, the ink looks perfectly fine.

It's not the inks, it's the method. Based on this analysis, it is pretty clear that using the wavelength of minimum reflectance to compute TVI can be extremely misleading for a large number of inks. While it may work well for many inks, it is risky. It is my stance that this method should be officially deprecated!

**Can we adapt the TVI formula?**

What about going back to the Status T or E filters? Referring back to the spectral plots of the blue tone ramp (Figure 4), it can be easily seen that a standard density filter would not solve the problem. The obvious filter would be the red filter (used to measure cyan ink). This blue ink behaves pretty much the same over the entire range for the red filter (600 nm to 700 nm), so we can expect similar results. The spectral plot for the orange filter has not been shown, but the conclusion is the same. The ideal density filter for orange is the blue filter, and the spectral plots of the tone values of the orange ink are similar across the entire range of the blue filter.

Perhaps there is another way to select the wavelength range that would work better? For Figure 4 (the blue ink) there is a fairly smooth fan-out around 450 nm, so there is a possibility for this ink. Looking at Figure 7, however, the shadows tend to bunch up at all wavelengths. This ink would appear to have extreme TVI no matter what section of the spectra we look at. Contrary to this, Figure 8 shows that the shadows are quite clearly differentiated.

My conclusion is that any variant on the standard Murray-Davies type formula for TVI can be misleading. Perhaps there is another way?

**Candidate alternatives to TVI**

Bill Birkett (Doppleganger) and Chuck Spontelli (Bowling Green State University) presented papers at TAGA in 2004 and 2005, and came to CGATS with a suggestion in 2005 for a different way to calculate a TVI-like parameter, which that called "colorimetric tone value". Their parameter is computed as a combination of the X, Y, and Z values, so it uses the entire spectrum. Thus, it presumably could perform better on an ink such as the blue one is Figure 4. Their method applies a nonlinear transform similar to the CIELAB transform, so presumably this method is a bit more tailored to the human eye.

Another option, VLT (Visual Linear Targeting) has been developed by Bodoni for the pressSIGN software. This proprietary calculation provides a viable alternative to TVI for assessment of halftones, setting target values, and developing plate curves. As the name implies, VLT is approximately linear with human vision. In this way, VLT will indicate the extent that, for example, details can be held in the shadow tones.

Mark Samworth has proposed another method, which he has called %ΔE-P. This calculation is based on the observation that halftones are generally laid out in CIELAB space fairly evenly. In other words, a 40% halftone will not fall far from the line between the substrate color and the solid color, and will be roughly 40% of the way from the substrate to the solid. The %ΔE-P parameter is the ratio of the color difference ($\Delta E_{ab}$) between the substrate and the halftone to the color difference between the substrate and the solid.

The goal for all inks, process or spot, is to adjust plate curves so that a 50% patch has a %ΔE-P of 50%.

Bodoni Systems' pressSIGN 5.1 has a feature called "Visual Linear Targeting" which is said to give a visual linear tone spread. The details are proprietary, but the VLT parameter appears to work in a way similar to %ΔE-P.

All the methods described so far provide a way to characterize how far a given halftone is between the substrate and the solid. For an ink like the orange ink in Figure 8, the relationship between the TVI-like parameter and the actual CIELAB value is simple. But most inks, such as the blue ink in Figure 5, there is a hue shift. The halftones do not live on the line between the substrate and the solid. For these inks, none of these parameters address the issue of specifying the CIELAB value of a given halftone.

TVI is based on the Murray-Davies equation, which is based on the physical model of hard dots, that is, dots with sharp edges. It was assumed that at the microscopic level, a halftone was made up of areas of solid ink, where the ink is the same color as the solid, and areas of substrate which have the same color as the substrate by itself. To determine TVI, the calculation determines the relative proportions of these two areas.

All of the assumptions in the Murray-Davies model are approximations. But real dots are soft. The ink thickness of a dot is less than that of a solid. The color of the substrate between dots is tinted by the solid. Pat Noffke and John Seymour have introduced a TVI-like parameter called dot hardness that is a single number (like TVI), but has the advantage of being able to pinpoint the color of a halftone in CIELAB space. If you know the spectra of the substrate, the solid, the input halftone value, and the dot hardness, you can approximate the CIELAB value of the halftone. This ultimately will be the ideal replacement for TVI for spot colors, as well as for CMYK.

## Onward

This is ongoing work within a subcommittee of Idealliance. The committee has yet to come to final conclusions. Stay tuned!

## Bibliography

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Birkett, William, and Charles Spontelli, *Colorimetric tone value (CTV) A proposed single-value measure for presswork*, presented to CGATS, July 26, 2005

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Noffke, Pat, and John Seymour, *A Universal Model for Halftone Reflectance*, TAGA 2012