USING TRANSLUCENCY STANDARDS TO EVALUATE COLOR INSTRUMENT LATERAL DIFFUSION ERRORS

David L. Spooner*

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Abstract: At three previous TAGA meetings, the author has presented papers on Lateral Diffusion (aka Translucent Blurring and Edge Loss) error. The method used for measuring this error was specific to one instrument and, in general, could not be used to determine the error characteristics of the many handheld portable instruments commonly used to measure printed products. This paper details the results of an investigation which revealed a relationship between measurements made with the sample moved back from the normal measuring position and the errors encountered when samples with various translucencies are measured in the normal manner with instruments with various illumination and viewing apertures. The discovery of this relationship holds the potential for determining corrections for lateral diffusion errors with 45/0 and 0/45 instruments without knowledge of the instrument aperture sizes and the sample translucency.

Introduction

At the 1991, 1993, and 1994 annual TAGA meetings the author has presented papers [1,2,3] on various aspects of the lateral diffusion errors (LDE) encountered when small aperture area spectrophotometers, colorimeters, and densitometers are used to measure slightly translucent materials (e. g. paper). This error results when the photometric measuring system of the instrument does not collect all of the light reflected by the sample.

As a review of the process, we have included figure 1 (next page) to illustrate one of the instrument illumination and viewing configurations in which not all of the reflected light is viewed by the detection system. This cross-section view of the

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*rhoMetric Associates, Ltd.
Wilmington, DE 19802-2933

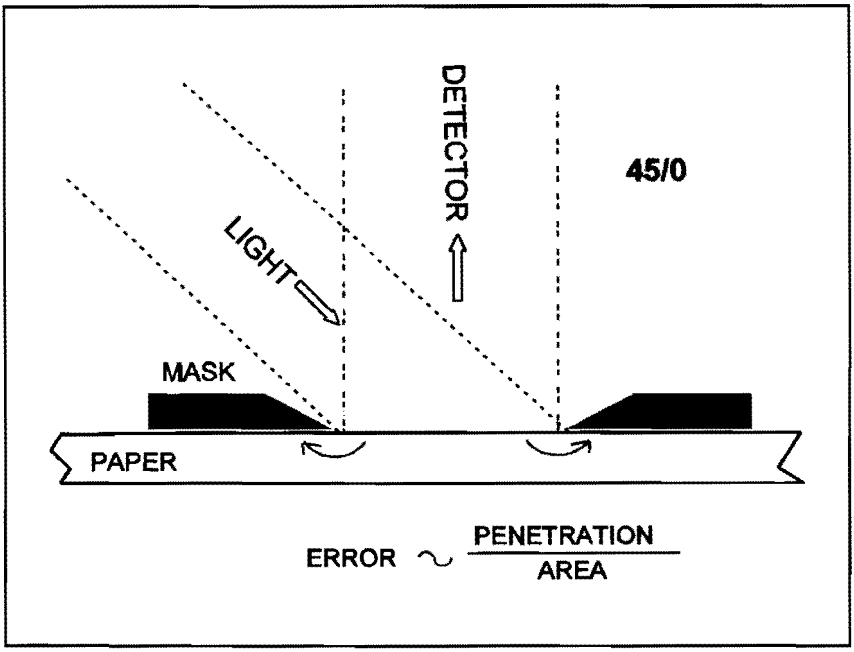

Figure 1 *When a translucent sample is measured, some of the light diffuses laterally before re-emerging from the sample. If the viewed and illuminated areas are the same, the detector will not see all of the reflected light.*

instrument shows a sample being illuminated by a light beam with a 45° incidence angle relative to the surface normal. The exact area illuminated is viewed from a surface normal direction by the instrument detector system. If the sample is not translucent (e. g. a grained aluminum printing plate), all of the area reflecting light will be viewed by the detector. Unfortunately, most samples are, to some degree, translucent. In those cases, some fraction of illuminating light diffuses sideways (i. e. laterally) before re-emerging from the sample surface as reflected light. In figure 1, the curved arrows are used to represent this process. If the area viewed by the detector is very nearly the same as the illuminated area , some of the light that diffuses lateral before emerging from the surface will not be viewed by the detector.

One solution to this problem is to make the area viewed by the detector larger than the illuminated area either by increasing the detector viewing area or decreasing the illuminated area. This allows the detector to view all of the light that laterally diffuses before emerging from the surface. The size difference between the illuminated and viewed areas that is needed to collect all of the light depends on the translucency of the samples being measured. In the case of photographic papers and many printing papers, making one of the areas 2mm on the side larger than the other[4] will suffice. When lightly pigmented plastics are measured, even larger area differences are needed.

It should be noted that four different, but equivalent, 45 and 0 degree illumination and viewing configurations can be used in colorimetric and densitometric reflectance measuring instruments. They are: a) 45° illumination with 0° (i. e. surface normal) viewing with the viewing area larger than the illuminated area; b) 45° illumination with 0° viewing with the illuminated area larger than the viewing area; c) 0° illumination with 45° viewing with the viewing area larger than the illuminated area; and d) 0° illumination with 45° viewing with the illuminated area larger than the viewing area. The Helmholtz reciprocity principal prescribes that these four configurations will be equivalent when the samples being measured are not optically active[5]. (Papers and inks normally used in graphics arts do not exhibit optical activity.)

THE USE OF NON-INVASIVE METHODS FOR ERROR DETERMINATION

The instrument that was used in our early investigations of LDE had a removable aperture plate. The size of the aperture determined the size of the sample area that was illuminated. Plates with different aperture sizes could be easily made by a simple machining procedure or by manually cutting holes in thin, black, plastic sheeting. An estimation of the LDE was calculated by making measurements of the same sample using plates with various sized apertures while maintaining the same viewing area (e. g. 3mm). In this manner, we were able to see the effect of illumination area over a range of 4 to 31mm.

This use of these various aperture plates was relatively non-invasive, in that the instrument could be returned to its original physical state by simply installing the original aperture plate. Most portable instruments do not allow this ease of changing aperture sizes. In some cases the instrument would need to be disassembled to change the apertures. In this respect, we might say that determining the LDE characteristics of these instruments and its interaction with samples of unknown translucency requires an invasive procedure. Some other instruments do provide optics and apertures for more than one view/illumination area combination. However, the combinations generally are so limited that it is not possible to do a complete characterization of the LDE characteristics of the instrument.

At the 1995 IS&T/SPIE Electronic Imaging Color Hard Copy Conference, the author presented a paper on a non-invasive method for determining the interaction of instruments with samples containing fluorescent materials[6]. In this paper it was shown that the relative intensity of the fluorescent exciting UV in an instrument light source could be determined by comparing the measured spectral reflectance of a standard reference material (SRM) containing a fluorescent whitening agent (FWA) with that of a similar SRM that was formulated without the FWA. The relative illumination UV content ranking of four instruments was determined using this method. Next, it was shown that this same relative ranking could be obtained by measuring a sample containing FWA with and without a UV rejection filter on top of the sample provided that the effective transmission of the filter was known. (This effective filter transmission was determined by measuring the spectral reflectance of a non-fluorescent SRM with and without the filter in place.) Finally, this method was used to determine the relative effect of fluorescence on the measured reflectance of paper samples which contained unknown amounts of FWA.

Some instruments internally include a UV rejection filter which can be, on command (electromechanical or mechanical), be inserted at some point into the light path of the instrument illumination. Comparison of measurements of a FWA containing sample made with and without the filter in place with similar measurements of a non-fluorescent SRM gives an indication of effects of the FWA containing sample as measured with the particular instrument. Installation of such a UV filter feature into an instrument that was not designed for such modification (e. g. the case with most portable instruments) would be difficult for anyone not skilled in instrument repair.

Making measurements with a UV cut-off filter placed over the sample provides a quick method of gathering data on the effects of FWA with instruments that do not employ internal UV filters as well as instruments that can not be modified with the installation of a filter. It is particularly useful when making and comparing measurements of the same samples with several instruments. However, as pointed out in the paper, the use of the filter does add two optical interfaces to the measurement path. For the most part, this does not cause problems, however, one paper sample which a fuzzy soft surface did give an anomalous value for FWA content. For this reason the method was defined as a method that gives qualitative information. What ever else, the method is non-invasive to the instrument structure.

A NON-INVASIVE METHOD FOR DETERMINING RELATIVE LATERAL DIFFUSION ERRORS

During the course of earlier, but unreported, work on measuring the LDE of various sample and instrument aperture combinations, a sample of flash opal glass was measured. (Flash opal glass consist of a clear glass with an opal glass layer on one surface.) The value of the LDE of the sample depended on which side of the glass was placed next to the instrument port. The LDE was highest when the opal layer was viewed through the clear glass layer. This experience with the flash opal and the placing of the UV filter on the FWA containing samples gave rise to the idea that it might be possible to determine the LDE characteristic of a given instrument by measuring the reflectance of SRM samples of know translucency with and without a layer of clear glass or plastic between the sample and the instrument port. Our experience of problems with the extra optical interfaces in the FWA work soon made it apparent that the clear material could be dispensed with in favor of measuring the sample at various distances from the instrument port.

The translucent SRMs used were FTS numbers 75, 85, and 93[7] (these numbers refer to the contrast ratios of the SRMs as calculated when they are measure with black and white backing). It was pointed out in our previous LDE papers that the SRMs supplied with most instruments for calibration are translucent. In the past, we have referenced all measurements to a press pellet of a mixture of barium sulfate and chromium dioxide with a nominal 50% reflectance. In this work, we used a FTS green 39 color plaque as a reference standard (50 - 60% reflectance). All comparisons were made with the 600nm wavelength where the material has a absorbance peak.

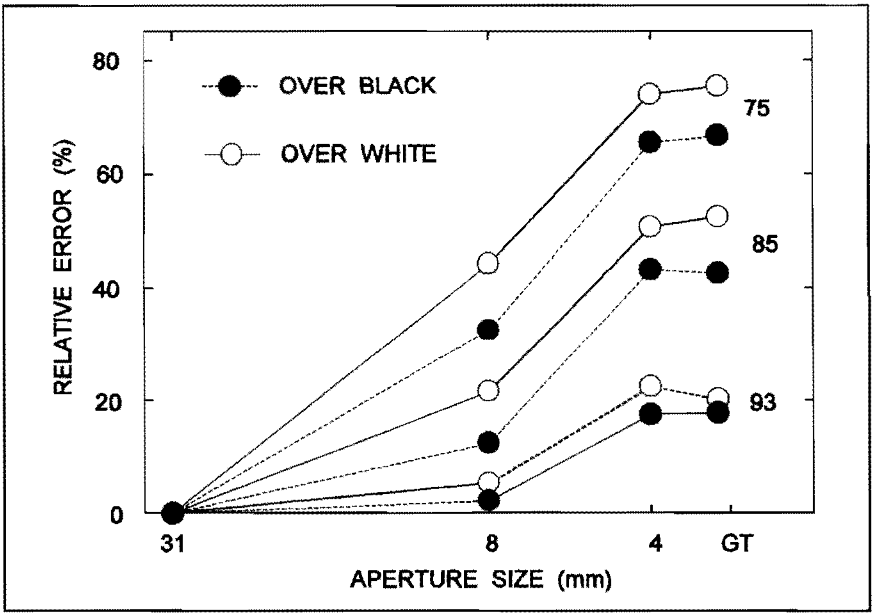

Figure 2 *Relative LDE as a function of illumination aperture size for samples used in this study.*

Figure 2 shows plots of the LDE for each of the translucent SRMs measured over black and over white and normalized to the 3mm view and 31mm illumination measurements. The second and third points on each curve are the error values for 3mm view and 8mm illumination and 3mm view and 4mm illumination. The end point on each curve is the error values obtained with measurements made with an OEM version of a popular portable spectrophotometer. As we have previous noted in other papers, the LDE of samples measured with a white backing is greater than the LDE of the same sample measured over a black backing. It should also be noted that all of the SRMs used in this work are more translucent than the most of the papers used for printing.

We know that the measured reflectance values of translucent samples taken with small aperture instruments are lower than the true reflectance values (i. e. measurements made with large illumination area and small view area or small illumination and large view) and that the LDE increases as the sample translucency increases. Surprisingly, when the sample is moved away from the instrument port, the reflectance relative to the on-port value is higher for the samples with the higher translucency. The diagram in figure 3 may aid in explaining this phenomena. It shows

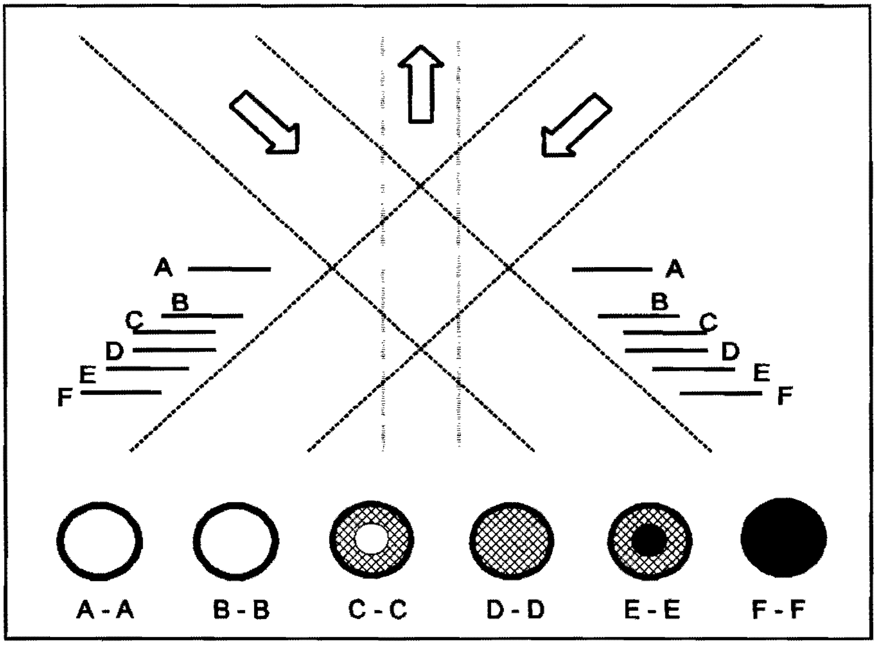

Figure 3

a schematic of the cross-section of a measurement configuration which employs a 45° incident annular source and a detector channel that views the sample in the surface normal direction. Note that for the purposes of this explanation, the illumination, represented by the downward pointing arrows, and viewing channel, represented by the upward pointing arrow, are assumed to be collimated (i. e. neither diverging or converging). Also, the patterns (i. e. the circular patterns in the lower portion of the figure) represent the light patterns which would be seen (i. e. projected) on a non-translucent sample (e. g. grained aluminum).

In this figure, position A is the normal sample measuring position. This gives adequate over illumination to minimize the LDE that might otherwise be present when a slightly translucent sample is measured. The circular area labeled A shows what the detector channel would see. If the sample is positioned at B, the detector would see what is in the circular area labeled B provided that the sample is not translucent - with a translucent sample the area would not be as bright. When the sample is positioned at C, the outer edges of the view area would be dimly illuminated and the center would be brightly illuminated. When the sample is positioned at D, the area of the viewed by the detector will be dimly illuminated. With the sample at position E, a black spot will be present at the center of the of the area viewed by the detector. At position F and beyond, the area viewed by the detector would be total unilluminated. Note that all of these patterns are those that the detector would view if the sample is non-translucent. If the sample is translucent, the light levels detected at positions E and F will be higher due to light laterally diffusing in from the areas of the sample that are more brightly illuminated but not viewed by the detector.

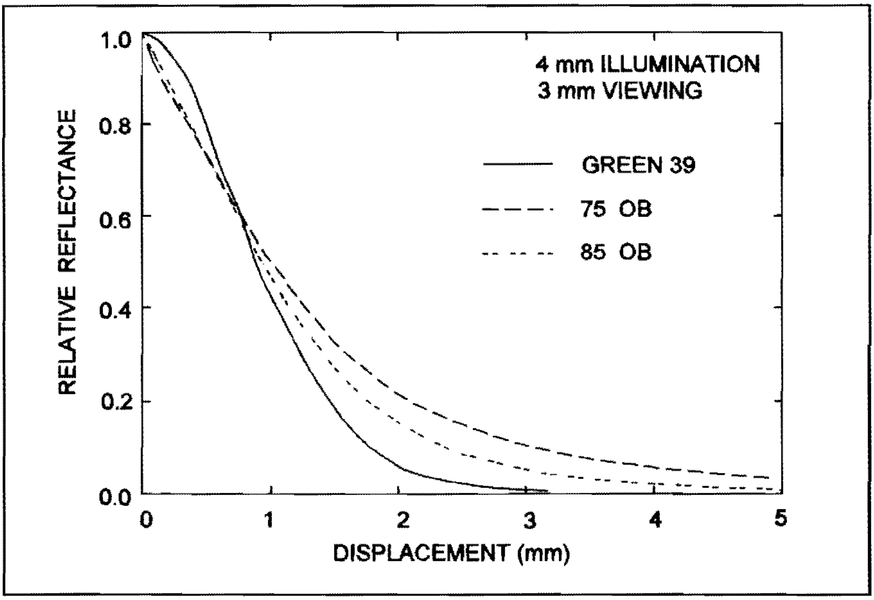

Figure 4 *Comparison of off-port reflectance measurements of two translucent samples and the FTS Green 39 standard.*

Figure 4 shows plots of the 600nm reflectance of the FTS green 39 reference and two of the translucent SRMs, FTS 75 and 85 measured over black, as a function of distance from instrument port for a 3mm diameter view and a 4mm diameter on-port illumination. The plotted reflectances are each normalized by the on-port, zero displacement, reflectances. When the samples are very near the port, the green 39 reference gives a higher normalized reading than the translucent samples. However, when the samples are moved back further the translucent samples give higher normalized readings than that of the standard. The greatest spread in the readings appears to be at about 2mm displacement which is the point at which the transition from a bight center spot to a dark center spot occurs on the illumination (i. e. position C in figure 3).

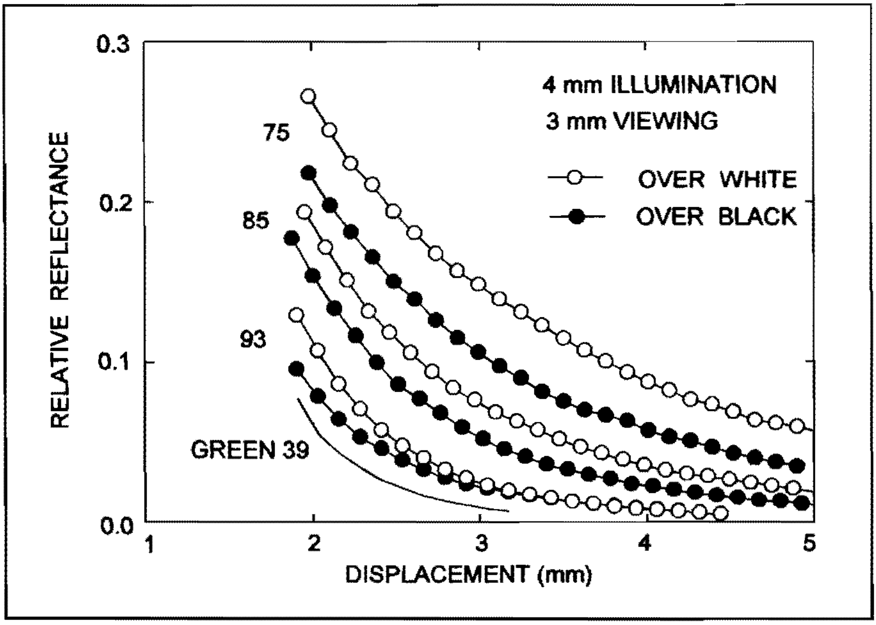

Figure 5 *Relative reflectance for samples at distances of 2mm and more from the instrument port.*

Figure 5 is an expanded version of figure 4 in which the data for all of the samples is plotted for displacements greater than 2mm. The increase in normalized reflectance in the region around 2 to 2.5mm displacement correlates with the LDE for the samples which was plotted in figure 2.

The lower curve in figure 6 (next page) shows the differences between the 2mm sample displacement green 39 reference value and the various translucent sample values at 2mm distance plotted against the relative LDE of the samples. The other two curves are similar data for the handheld portable instrument (GT) at 2mm sample displacement and the 8mm illumination - 3mm viewing instrument at a 5mm sample displacement.

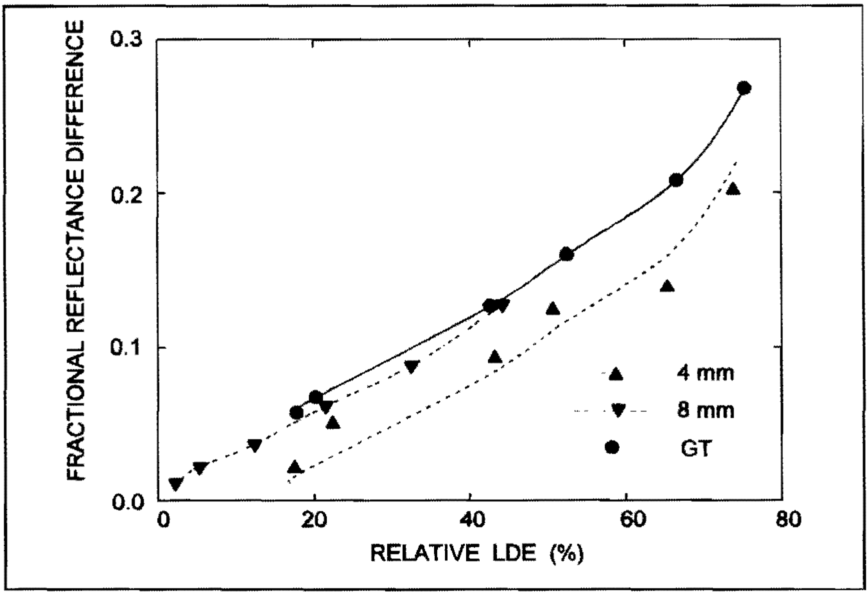

Figure 6 *Comparison of LDE and reflectance difference relative to the grren 39 standard - see text for details.*

DISCUSSION

The translucent SRMs used in this investigation are more translucent than most graphic arts substrates (e. g. paper). Further investigation using various papers is needed to prove this method's potential usefulness for measurement of printed products. Such an investigation should include samples which are overprinted with both solid and half-tone screen ink patterns. Also, some investigation into its usefulness with instruments which employ hemispherical collection or illumination geometry should be conducted.

CONCLUSIONS

The availability of SRMs with known translucency materially aided this investigation. It appears that with further refinement of the method it may be possible to obtain reflectance data which has been corrected for LDE by making an on-port and a displaced sample measurement and applying a correction factor which has been previously derived during a one-time calibration of the instrument.

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