The Color Measurement Standard for the Graphic Arts

Sappi Printer Technical Service

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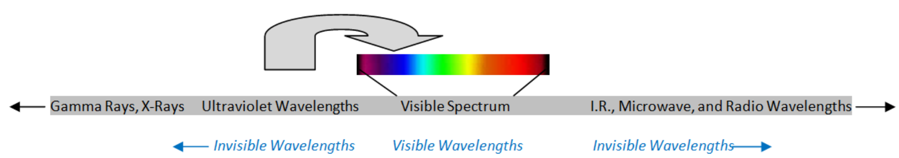
An Overview of ISO 13655:2009 Graphic Technology—Spectral Measurement and Colorimetric Computation for Graphic Arts Images

Introduction—Optical Brighteners and the Challenges for Accurate Color Measurement

In response to the design community and the graphic arts industry's demand for brighter "blue white" papers, fine paper manufacturers commonly add fluorescent dyes called optical brightening agents (OBAs) to commercial printing papers. These chemicals have the unique ability to absorb ultraviolet radiation and then transform and re-emit invisible U.V. wavelengths as high energy photons of light in the violet/blue area of the visible spectrum—a phenomenon called fluorescence. Invisible U.V. wavelengths such as contained in sunlight and, to varying degrees in many artificial light sources, are therefore absorbed by optical brightening agents in fine printing papers and transformed into wavelengths of energy perceivable to human viewing; thereby becoming "visible" light radiating from the paper's surface.

The Electromagnetic Spectrum



Optical brightening agents absorb invisible ultraviolet wavelengths of energy and cause that energy to be re-emitted (fluoresce) as perceptible light in the violet/blue portion of the visible spectrum

The total amount of light reflected from paper is determined by several factors, including physical surface characteristics (gloss, smoothness, etc.), the quantity and characteristics of the optical brighteners, and the spectral power distribution and intensity of the illuminant (including the amount of U.V. energy radiated by the illuminant). When illuminated by a light source that contains a significant amount of U.V. energy, the energy transference process (from invisible to visible wavelengths) is activated and an optical brightener enhanced paper may actually reflect more total light than it receives from the light source (i.e., visible light reflected from the light source + re-emitted "blue" light transferred from the invisible realm of the electromagnetic spectrum). The result is a paper that can appear very bright and has an aesthetically pleasing, slightly blue, color cast.

We may think of U.V. energy as a "variable switch" that activates and controls the (blue) light re-emitting process of fluorescence. Therefore, it is no surprise that variability in the amount of U.V. energy radiated by a light source can cause dramatic

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shifts in the visually perceived color of an image printed on a paper that contains optical brighteners (especially in highlight to mid-tone screen values where paper shade is a significant influencer of color). Likewise, when performing color measurements, the amount of U.V. energy emitted by the light source of the instrument (i.e., the spectrophotometer, colorimeter, etc.) variably affects the amount of blue light that fluoresces from the sample.

Fine printing papers enhanced by optical brightening agents give printers the ability to produce vibrant color images in contrast with crisp bright white spaces. However, we can all agree that the presence of optical brightening agents in fine printing papers can also create unique challenges for printers, prepress professionals, and others who seek to accurately measure and communicate the properties of color.[1] When we observe a "high-bright" paper in a viewing condition where U.V. energy is present in the illuminant, our visual perception quickly adapts to the additional blue wavelengths of light and we simply see "bright white." Spectrophotometers, however, aren't so easily deceived. They will measure a U.V. stimulated, optically brightened paper/printed image as actually being bluer (and bluer to varying degrees depending on the U.V. content of the illuminant contained within the measuring instrument). This creates quite a problem for color management systems since profiling software will typically compensate for the perceived "blueness" of paper and printed images by adding varying amounts of the complementary color—yellow. The resulting characterization profile can lead to print output that is tainted with a yellow cast readily visible from highlight to mid-tone.

Variability and unpredictability in color perception and color measurement are the nemeses of stable color control, accurate color communication, and reliable color management. Color management processes, print production color control systems, and precise global color communication depend on accurate color measurement data. Imagine the practical consequences that can occur with variable stimulation of optical brighteners resulting in differing amounts of blue light reflecting back to the measurement device. To meet the graphic arts industry's need for more precision in color measurement and communication methodologies, the International Organization for Standardization revised the longstanding ISO 13566:1996 standard and established ISO 13655:2009 Graphic technology—Spectral measurement and colorimetric computation for graphics arts images. In the same year the standard for visual color assessment (ISO 3664:2009) was also revised. The two standards complement each other as both mandate operating conditions that require close control of the U.V. wavelengths in the specified illuminants used for **viewing** and **measuring** color.

ISO 13655:2009 defines four comprehensive color measurement models, i.e., measurement conditions, that can be used to accurately quantify spectral and colorimetric properties of color.

1 It should be noted that some inks and toners as well as many aqueous coatings also contain optical brightening components.

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Measurement Condition M0

Until the recent advent of new LED illuminant technologies, densitometers and spectrophotometers have used tungsten (incandescent) lamps that approximate the CIE standard illuminant A. This measurement methodology complied with the "old" ISO standard and the vast majority of color measurement instruments currently used in the graphic arts industry utilize incandescent/tungsten illuminant technology. In order to provide consistency with this longstanding measurement system, and to validate the relevance of the majority of color measurement devices currently in the field, ISO 13655:2009 has established the measurement condition M0. Measurement condition M0 supports the tungsten illumination technologies and maintains the validity of legacy colorimetric data.

One of the shortcomings of using measurement condition M0 is that it does not define or mandate control of the U.V. content of the illuminant. When a color measurement is made with a tungsten/Illuminant A instrument, and is said to "include U.V.," we don't necessarily know how much U.V. energy is being emitted by the illuminant. The spectral power distributions of tungsten lamps can vary quite significantly with respect to U.V. content. Measurement condition M0, therefore, is not the optimal choice when spectral or colorimetric data must be exchanged when papers and applied colorants (e.g., inks, toners, coatings) possess fluorescent properties.

To summarize; the broad definition of the measurement condition M0 maintains the practicality of the commonly used "legacy" instruments in the graphic arts industry and protects the viability of historical data derived with a variable U.V. content tungsten illuminant. Since most color measurement instruments in use around the world today align with M0, and current industry print standards, reference data sets, and standard published ICC profiles are based on data generated with measurement condition M0 equivalents, the M0 measurement condition will continue to be the industry's de facto standard for some time. One requirement that ISO 13655:2009 makes to ensure the accuracy of M0 data exchange is to specify that, at a minimum, instruments of like manufacturer and model must be used if shared data is to be deemed reliable.

Measurement Condition M1

The intent of measurement condition M1 is to provide consistency and accuracy in measurement data by stabilizing the effects of interaction between the illuminant and the fluorescing properties of the sample (due to optical brightening agents in the paper and/or fluorescence of applied inks, toners, and coatings). The M1 model provides correlation between measurement data and the visual assessment of color when viewed in conditions compliant with ISO 3664:2009.[2]

2 ISO 3664:2009 is the international standard which specifies viewing conditions for critical color assessment. ISO 3664:2009 mandates that the light source contain a U.V. component and comply with the spectral distribution defined by CIE illuminant D50.

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There are actually two subsets of the measurement condition M1 (i.e., two methods to achieve conformance):

M1-PART 1 (A FULL D50 APPROXIMATED MATCH)

Measurement condition M1-1 requires that the illuminant emitted by the measuring instrument closely simulate the CIE standard illuminant D50.[3] Using an illuminant with a controlled spectral power distribution (D50), containing a specified amount of U.V. energy, minimizes variations in measurement data caused by inconsistent stimulation of optical brighteners. Measurement condition M1-1 may be used for measurement of color when the paper and/or the applied colorants—i.e., inks, toners, etc. contain fluorescent properties. New measurement instruments are being introduced to the graphic arts industry which support the M1-1 measurement model.

M1-PART 2 (A U.V. COMPENSATION METHODOLOGY)

M1-Part 2 allows a different path to M1 conformance—simulation of the effect of the D50 illumination condition by applying a compensation methodology to correct for the presence of fluorescence in the substrate. M1-2 is used only for color measurements when the fluorescent properties of paper must be captured and compensated for. M1-2 is not to be used for color measurement of images where inks, toners, etc. may contain any amount of optical brightening agents; it is only applicable for color measurement of images printed with non-fluorescing colorants on OBA enhanced paper. Details as to the practical application of measurement condition M1-Part 2 are beyond the scope of this article.

It is important to remember that two major sources of potential error come into play when color must be measured on optical brightener enhanced papers and applied colorants. First of all, the variability of the optical brightener content of the substrate (and/or that of the applied inks, toners, and coatings). Secondly, the variability of the optical brightener stimulant—i.e., the U.V. content of the illuminant. Although measurement condition M1 can't help us with the first concern, M1 definitely brings stability to the illuminant condition resulting in more reliable color measurement data and better inter-instrument agreement.

Measurement Condition M2

Measurement condition M2 specifies complete exclusion of U.V. from the source illuminant and, therefore, precludes the effects of fluorescence from the measurement data. Exclusion of the U.V. wavelengths may be accomplished through

3 In the literal sense, an illuminant is a source of visible light with a defined spectral power distribution profile. The International Commission on Illumination (usually abbreviated CIE for its French name: Commission Internationale de l'Eclairage) is one of the groups responsible for defining and publishing "standard illuminants." CIE illuminant D50 is defined in CIE 15-2004 and represents a theoretical phase of natural daylight. Due to the necessity for a common industry-wide standard, international committees have agreed that a source of illumination approximating natural daylight is the best choice.

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appropriate design of the source illuminant or by means of inserting a U.V. cut filter in the path of the illuminant. M2 provides a test to ensure that regardless of the light source (e.g., tungsten/CIE illuminant A, CIE illuminant D50, etc.) appropriate suppression of the U.V. portion of the spectral power distribution is applied. M2 is useful for measuring the color of non-fluorescing inks independent of the contributing effects of optical brightener enhanced papers.

It should be noted that if the samples being measured do not contain optical brightening agents, the results of measurement conditions M0 and M2 will ideally be the same.

Measurement Condition M3

Measurement condition M3 minimizes the effects of surface reflection by adding a polarization filter. M3 mandates that in addition to suppressing the effects of reflection, the measurement condition must also be void of U.V. energy so as not to stimulate fluorescence, as defined by measurement condition M2. In essence, M3 = M2 + a polarization filter.

Polarization filtering removes surface reflections and reflections from wet ink films, therefore creating less difference in measurement between wet and dried-back ink.

Finally, it should be noted that the four measurement conditions specified by ISO 13655:2009 may be used for both colorimetric (e.g., CIE Lab, CIE XYZ, CIE LCh, etc.) and densitometric (e.g., density, TVI, trapping, etc.) functions.

Other Considerations of ISO 13655:2009

In addition to specifying the four measurement condition choices, ISO 13655:2009 also includes standardization of other components of the spectral measurement and color computation methodology which include:

— *Sample backing materials* (white, black)[4]

— *Measurement geometry* (45°:0° or 0°:45° and other considerations)

— *Methods for data reporting*

— *Colorimetric computation requirements and standard observer geometry.* To provide consistency with viewing conditions defined by ISO 3664:2009, colorimetric measurements shall be made at 10 nm intervals using the CIE illuminant D50. The 2° standard colorimetric observer is preferred because it more closely matches the conditions under which printed material is viewed.

4 Self backing with multiple unprinted sheets of the specimen substrate is preferred in the paper and ink making industries. However, only standard black or white backing falls within the scope of ISO 13655:2009.

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Specification of Paper Properties

As its title states, ISO 13655:2009 is the international standard for spectral measurement and colorimetric computation for graphic arts printed images. The provisions of the Standard may be used in the graphics industry for certain color monitoring, color control, and color management applications including measurement of the white point of the print media (e.g., the printing paper). ISO 13655:2009, however, may not be used as a basis for establishing and communicating paper product specifications. Paper specification protocol is defined in other ISO standards.

Communication of Measurement Data

As color management and print production workflows become increasingly reliant on numeric color measurement data, it is essential that the measurement methodology is carefully chosen to suit the specific needs of the application. The choice of measurement conditions can result in very different data sets being produced for the same color sample. Therefore, when communicating the properties of color, it is important that the source of the data be accurately defined and communicated. When exchanging spectral and colorimetric data, ISO 13655:2009 requires that a statement containing the following information accompany the measurement data:

- A statement that measurements and computations are in conformance with the ISO 13655:2009 Standard
- The measurement condition used (M0, M1, M2, M3)
- The specimen backing used (white, black)
- Measurement instrument brand and model

When exchanging measurement data for comparison to established legacy targets and printing specification aim points, and in order to provide optimal clarity of data communication, it is a best practice to provide additional measurement and color computation information (e.g., illuminant/standard observer: D50/2° or D65/10°, measurement geometry: 45°:0° or 0°:45°). When specifying density and densitometric functions (density, TVI, trapping, etc.), the M0 measurement condition is generally used.[5] It is, however, important to attach measurement condition information to the data along with the density status (typically status T).

5 ISO 13655:2009 is consistent with ISO5-3:2009 which specifies the standards for measuring densities.

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Conclusion

ISO 13655:2009 brings much needed clarity and standardization to the subject of spectral measurement and colorimetric computation in the graphic arts industry. The specification of measurement conditions has resulted in an emerging new generation of spectral measurement instrumentation that allows the industry to control processes and communicate the properties of color with unprecedented accuracy. The key to process control, system repeatability, accurate color rendition, and exacting color communication when optical brightening agents are introduced into the workflow, is a precisely defined illuminant system that stimulates fluorescence in a consistently repeatable manner. ISO 13655:2009 brings consistency to the measurement condition by controlling the U.V. output of the illuminant (specifically in the M1 measurement condition) in similar manner as ISO 3664:2009 brings consistency of optical brightener stimulation to the viewing condition. Therefore, color that is properly and accurately viewed can also be accurately measured and specified. As mentioned earlier, measurement condition M0 will continue to be the de facto standard in practice until new instruments become commonplace throughout the industry. As the measurement conditions specified in ISO 13655:2009 are implemented industry wide, new characterization data sets, reference print specifications, and ICC color profiles (e.g., GRACoL, SWOP, etc.) will emerge and be integrated into process workflows.

As a service to our customers, Sappi Fine Paper North America provides CIE LAB data of paper white point targets upon request specified in both M0 and M1 measurement conditions.

Summary of the Measurement Conditions

MEASUREMENT CONDITION M0

- Uses a tungsten light source that approximates the CIE illuminant A
- The U.V. content of the illuminant is neither defined nor controlled
- Provides accommodation of most graphic arts color measurement instruments presently in the field
- Currently the de facto measurement condition for the graphic arts industry and used to provide the measurement data for several common print specifications and reference print conditions
- Potential for significant instrument-to-instrument variability

MEASUREMENT CONDITION M1 (TWO PARTS)

Part 1

- Defines the spectral power distribution of the measurement device's source illuminant –CIE illuminant D50

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- Used to measure the effects of fluorescence in both papers and inks/toners/coatings

Part 2

- Uses a compensation methodology to correct for the effects of fluorescence of optical brighteners in the substrate (i.e., M1-2 simulates the effect of a source illuminant with a spectral match to CIE D50)
- Used to measure the effects of fluorescence in paper only

MEASUREMENT CONDITION M2

- Excludes U.V. from the source illuminant and, therefore, the effects of fluorescence from the measurement data (also known as U.V. cut)
- M2 is useful for measuring the spectral characteristics of non-fluorescing inks independent of the contributing effects of optical brightener enhanced papers

MEASUREMENT CONDITION M3

- Adds a polarization filter to the measurement condition M2
- Measurement condition M3 eliminates fluorescence and reduces the influences of surface reflection

Reference

ISO 13655:2009, *Graphic technology – Spectral measurement and colorimetric computation for graphic arts images*

Other questions?

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