The Color Viewing Standard for the Graphic Arts

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An Overview of ISO 3664:2009 Graphic Technology and Photography—Viewing Conditions

Introduction

Color is the result of interaction between light, an object, and a viewer. The sensation of color is achieved as unique combinations of wavelengths of light are transmitted, reflected, or emitted to the viewer. Since the properties of light are a primary component of color, and different lighting conditions will produce differences in color rendition, it is vital that critical color assessment be conducted within viewing conditions where lighting is standardized and components affecting the viewing environment are closely controlled. Color decisions can only be made and communicated accurately if all participants involved utilize internationally standardized viewing (which includes lighting) conditions.

ISO 3664 has long been the international standard that specifies viewing conditions for critical color evaluation of images rendered on both reflective and transmissive media; as well as for images displayed by color monitors. The ISO 3664 standard underwent its second revision in May 2009 with the intent of optimizing the accuracy of critical color assessment. The revised standard, ISO 3664:2009, went into effect internationally on January 1, 2012.[1] ISO 3664:2009 addresses several facets of the viewing condition including spectral characteristics of the illuminant, intensity of illumination, uniformity of illumination, the physical conditions of the viewing environment (including characteristics of the viewing surround and control of ambient interference), and specifications for viewing geometry and the backing of a viewed image.

Illuminant Definition

ISO 3664:2009 specifies the CIE illuminant D50 with a correlated color temperature of approximately 5000° Kelvin as the standard illuminant to be used as a light source for viewing and assessing color for the graphic technologies and photography.[2] ISO 3664:2009 differs from previous versions of ISO 3664 in that it requires the illuminant to more closely emulate the "true" CIE defined D50/*daylight* spectrum by including a specified amount of U.V. energy in its spectral power distribution. The former specifications allowed for a very loose approximation of CIE D50 by permitting the virtual exclusion of U.V. energy from the illuminant. With ISO 3664:2009, the tolerable range of deviation from the standard CIE D50 illuminant definition has been

1 ISO 3664 was first ratified in 1975. The standard was revised in 2000 and published as ISO 3664:2000. ISO 3664:2009 is the third version of the standard.

2 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.

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significantly minimized.

ISO 3664:2009 also states that the light source must ensure a certain quality of illumination, i.e., spectral stability and color reproduction accuracy, by having a general CRI (color rendering index) of 90 or greater.[3]

Why the CIE Illuminant D50?

Clearly, the best viewing condition for assessment of color is that in which the product or subject will ultimately be displayed. However, due to the necessity for a common industry-wide standard, international committees have agreed that a source of illumination approximating a particular condition of natural daylight is the best choice. By mandating use of a precisely defined spectrum of illumination, the standard CIE illuminant D50, ISO 3664:2009 ensures the most representative lighting condition to simulate the average spectral power distribution of natural daylight.

It is important to note that the presence of U.V. energy in the spectral distribution of the D50 illuminant will significantly amplify the visible effects of optical brighteners contained in fine printing papers, some proofing media, as well as in certain inks and toners, and in various aqueous and U.V. coating formulations.

Due in part to their significant contributions to the effects of metamerism[4], the presence of optical brighteners have always been a problematic variable for

3 The color rendering properties of light sources are classified by a Color Rendering Index (CRI) value. CRI quantifies the ability of a light source to accurately reproduce the color of standard test objects as compared to the illumination of the same standard test objects by a reference illuminant of the same color temperature. In other words, CRI quantifies the ability of a light source to accurately render all frequencies of its particular specified power distribution profile. CRI is a relative value (index) with respect to a specific reference illuminant, measured on a scale of 1-100. The higher the CRI rating, the more accurately a light source is at rendering color when compared to a "reference" illuminant of the same type and color temperature. A CRI value of 100 means that a light source will represent color exactly the same as the reference illuminant.

4 When two objects render different spectral power distributions yet visually match under a certain lighting/viewing condition, but not under another, the phenomenon is called metamerism. Two objects that visually match under at least one lighting condition are called a metameric pair. When two objects match under one light source/viewing condition but not under another, the resulting condition is called metameric failure. Daylight projects relatively balanced spectral power distribution; meaning that in white light, every color in the visual spectrum (red, orange, yellow, green, blue, indigo and violet) is present with nearly the same intensity. Artificial light sources will spike in different wavelengths of the spectra that they radiate. When unbalanced artificial light sources meet with the different reflective properties of two objects, color will be reflected to the observer according the unique spectrum of each light source and metamerism can occur.

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comparative color viewing, color management, predicting outcomes on press, and print process control. Implementation of the ISO 3664:2009 specified viewing conditions will expose color complications that might arise from the presence of optical brighteners in the printing system; allowing those challenges to be realized earlier in the color management workflow where they can be addressed preemptively and more efficiently.

For the purpose of illustration, consider a printed image and a contract color proof which are a "metameric" match when viewed under a certain lighting condition void of significant U.V. energy (e.g., such as office lighting or even in a viewing booth equipped with the "old style" 5000K/D50 lamps). When viewed outdoors or in lighting conditions that contain U.V. energy, the two no longer match. What happened? The presence of U.V. energy in the light source causes the optical brighteners in the printed piece (e.g., fine paper + ink + aqueous coating) to fluoresce and re-emit color (light) in the lower spectral wavelengths—dramatically affecting the color of the printed image. Since the particular proofing media in our example contains little to no optical brighteners, the color of the contract proof appears virtually the same as it did in the non-U.V. lighting condition. The result: color mismatch (metameric failure) between the print and the proof. Color differences resulting from the effects of optical brighteners are generally most noticeable in the lower end of the tonal scale (highlight to mid-tone)—areas where the optical contributions of paper and overcoats are highly relevant.[5]

As demonstrated by the illustration, creating a metameric color "match" (i.e., the creation of a unique metameric pair) in one specific viewing environment (one which typically excludes U.V. from the illuminant) is generally not a practical or widely useful match. In reality, a metameric color match can be highly misleading and may create false expectations of a printed product. To guard against this phenomenon, ISO 3664:2009 mandates a much lower tolerance for metamerism (i.e., a lower metamerism index) than did the previous version of ISO 3664 by specifying a close approximation of the standard CIE D50 illuminant that contains precisely balanced spectral power distribution—including U.V. wavelengths. Therefore, ISO 3664:2009 prevents the "surprise" of unexpected metameric failure; i.e., as the color of two objects may match under one light source and viewing condition but not in another.

5 Optical brightener/U.V. interactions are not by any means the only contributor to the effects of metamerism. Other contributors include various components of ink and toner pigments, gloss levels, substrate surface smoothness, etc. These and many other variables can all cause an object or a print to interact in different ways with the spectral inconsistencies of artificial light sources. Unbalanced and irregular combinations of light (color) are reflected back to the viewer when inconsistent combinations of wavelengths from artificial light sources meet objects with different light absorptive/reflective properties. Color stability between subjects can only be achieved when viewed under a spectrally balanced and stable illuminant and within a controlled viewing environment.

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Other Considerations of ISO 3664:2009

Since the level of illumination can appreciably affect the appearance of an image, the ISO 3664:2009 standard defines intensities of illumination. Two levels of illumination intensity are specified: a high intensity level to be used for critical image evaluation and comparison (allowing for full shadow illumination without washing out highlight areas), and a lower level of illumination intensity which is used for more practical evaluation of full tonal reproduction. It is assumed that the lower level of illumination intensity provides lighting in which the average viewer is most accustomed.

Maintaining uniformity of illumination throughout the plane of viewing is ensured by the Standard as luminance measurements are required for at least nine evenly spaced intervals across the viewing area.

Ambient light conditions can negatively influence precise color perception. Therefore, ISO 3664:2009 considers multiple components of the viewing *environment* in which reflective color and images displayed on color monitors are to be evaluated. While the Standard does not define standardization of all components of a viewing booth, it clearly specifies that the viewing environment conditions be designed to minimize any outside interference with color observation. In addition to controlling the color of the surroundings (including all surfaces of the viewing booth), and eliminating extraneous ambient light, it is critical that certain best practice geometries relating to the relative positions of the light source, the image, and the observer be followed.[6]

Recommendations

It is recommended by color scientists, along with the graphics arts, photographic, and color management communities, that the ISO 3664:2009 standard be fully implemented industry wide. All color viewing stations should be equipped with ISO 3664:2009 compliant tubes. In order to prevent color miscommunication and unnecessary metamerism issues, it is critical that *all partners* in the color communication process, and throughout the entire color managed workflow, closely follow the mandates of the Standard. Reference print specifications and characterization data sets are in the process of being brought into compliance with the ISO 3664:2009 viewing condition. Furthermore, the color measurement condition M1, a specification of the newly revised color measurement standard ISO 13655:2009, provides a true D50 color illuminant/measurement condition which is in alignment with the viewing conditions specified by ISO 3664:2009 (allowing us to

6 All inclusive viewing geometries are not specified by ISO 3664:2009. There are, however, published industry best practices which can be quite helpful when designing a color viewing station.

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accurately measure the color that we see).[7]

Those upgrading their color viewing conditions to align with ISO 3664:2009 should immediately inform all participants in the color workflow of the ramifications of such action. As we have previously mentioned, all involved must realize that since the ISO 3664:2009 compliant CIE D50 illuminant contains a considerable amount of U.V. energy, fine papers, some proofing media, specialty inks, coatings, etc., which contain optical brighteners, will now fluoresce to a greater degree under the new lighting/viewing condition. This may create significant problems when attempting to match proof-to-print since many proofing papers either do not contain optical brighteners or do not contain the levels typically found in fine printing papers. Matching previous press runs (those produced prior to the illuminant upgrade) may also be challenging.

If adoption of the standard CIE D50 illuminant creates insurmountable color matching problems, or if the change is undesirable for other reasons, ISO 3664:2009 allows for an exception—use of a U.V. filtering device. U.V. filtering lenses are available for viewing booths and will block the transmission of U.V. wavelength radiation, causing the light emitted from Standard compliant D50 tubes to create a power distribution spectrum similar to pre-ISO 3664:2009 "D50" illuminants. ISO 3664:2009 specifies that U.V. filtering lenses can be used to provide a viewing environment comparable to the M2 measurement condition (see footnote #7). It is critical, however, that if U.V. filtering is used at any time for color evaluation, **every partner in the workflow must follow the exact same practice.**[8]

It is important to note that for years, many in the graphic arts industry have believed 5000K to be the equivalent of D50. In fact, this association is not at all accurate. 5000 degrees Kelvin is a correlated color temperature[9] whereas D50 is a precisely defined spectral power distribution curve. The D50 illuminant may have a color temperature of 5000° Kelvin but not all 5000K light sources are manufactured to the D50 spectral definition. Even though the graphic arts industry at large is under continual pressure to lower operation costs, those who aim for an accurate rendition of color should not be tempted to purchase the inexpensive 5000K fluorescent tubes from the local home center! Remember, a variety of non-D50 spectral curves can

7 ISO 13655:2009 specifies the "M" series of color measurement conditions. The spectral power distribution specified in ISO 3664:2009 corresponds to the measurement condition M1. Measurement condition M2 requires U.V. exclusion by passing the illuminant of the spectral measurement tool through a U.V. cut filter (or by other means of U.V. exclusion).

8 ISO 3664:2009 allows for certain deviation from the Standard as long as the viewing condition is agreed upon in advance by all applicable parties (such deviation may include using the viewing condition in which a product will be exhibited).

9 Kelvin is a scale of measurement for temperature. When a black body radiator is heated to a temperature of 5000° K, the color of the light emitted is that which is associated with a phase of natural daylight. Higher color temperatures are associated with "bluer" light. Lower color temperatures produce "yellower" light.

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produce the equivalent of 5000°K. The potential cost of inaccurate color rendition is not worth the short term savings of economical lighting.

Finally, it is critical that all partners who evaluate color, or in any way contribute to the color managed workflow, follow a strict maintenance schedule for their color viewing stations. The spectral data at the surface of the viewing system/condition should be routinely assessed using a photometer or spectro-radiometer.

Conclusion

Compliance with ISO 3664:2009 encompasses addressing multiple factors relating both to the precise definition of the illuminant and to the specifics of the viewing environment as they simultaneously converge, *at the surface of viewing*, in interaction with the observer. While there is a great deal of discussion around the Standard in relation to definition of the illuminant, it is important to note that the totality of all specified components of ISO 3664:2009 interdependently comprise a compliant, standardized lighting/viewing condition. In other words, full compliance with ISO 3664:2009 is farther reaching than just upgrading light tubes. It also involves regulating the intensity and uniformity of illumination, controlling reflectance, ensuring the chromaticity value of the surround, managing ambient influences, etc.—anything that may affect illumination of the viewing surface and ultimately the reflected color of the object being viewed.[10]

Implementation of ISO 3664:2009 may seem complex but compliance with the Standard is essential for accurate assessment and communication of critical color. The viewing condition is one of the most overlooked aspects of color management. If everyone is judging color by the same standard, production costs can be reduced and post-production “disappointments” can be avoided. The key is ensuring that all partners in the workflow strictly follow the requirements of the International Standard.

To summarize:

— Standardized viewing conditions are critical for accurate color assessment and essential for precise color communication.

— ISO 3664:2009 defines the spectral characteristics of the illuminant, the quality of the light source, the quantity of illumination, and the physical viewing conditions.

— One of the most notable changes in the newly revised color viewing Standard for graphic technology and photography viewing conditions, is that the

10 Requirements for the surround of a viewing area and the backing of a viewed image are specified in 4.2.4 of ISO3664:2009. The Standard also states that the backing (white or black) shall be indentified when communicating the viewing condition for an image.

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illuminant must now contain U.V. wavelengths within a spectral profile that closely approximates a specific phase of natural daylight (i.e., as defined by the CIE illuminant D50 spectral power distribution).

- The presence of U.V. energy in the viewing illuminant will significantly increase the visible effects of optical brightening agents in papers, inks, coatings, etc. When lighting systems are upgraded with tubes that conform to the ISO 3664:2009 standard, the visual differences in the printed sheet (due to the presence of U.V. wavelengths in the D50 illuminant), will be most noticeable in the lower end of the tonal scale (highlight to midtone); areas where the optical contributions of paper and overcoats are most relevant.
- Contrary to the longstanding belief of many, 5000K does not equal D50. The D50 spectral power distribution curve, not 5000K, defines the standard illuminant for the graphic arts industry. A number of lighting manufacturers market lamps (tubes) with a correlated color temperature of 5000°K but unless the lamps are manufactured with a specified spectral power distribution of D50, the result will be erroneous color viewing, communication, and reproduction.
- With ISO 3664:2009 viewing conditions, what you see can now be what you get! An image viewed under ISO 3664:2009 conditions will be a close match to how the same image will appear in natural daylight conditions. Any color matching issues can be dealt with at press rather than realized after printing.
- Designers, color managers, printers, and end users alike who wish an accurate rendition of color must maintain *all* components of their viewing conditions according to ISO 3664:2009. ISO 3664:2009 requires not just D50 lamps, but a precise D50 illumination condition *at the surface of viewing*.
- Certain occasional deviations from Standard specifications (e.g., changes in the reference illuminant) are allowed as long as everyone in the color workflow follows the exact same procedure.
- In order to properly manage color reproduction, it is critical that high quality printing papers which contain consistent and stable optical brightening systems be specified.
- Non-ISO 3664:2009 compliant D50 tubes are no longer available for purchase from the major lighting system manufacturers.

Appendices

1. A copy of the International Standard *ISO 3664 (Third Edition 2009): Graphic technology and photography—Viewing conditions*, may be obtained (for a fee) from:

- International Organization for Standardization (ISO) at www.iso.org
- American National Standards Institute (ANSI) at www.ansi.org

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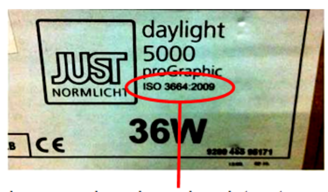
2. Identifying ISO 3664:2009 compliant lamps from two of the leading suppliers:

ISO 3664:2009 Compliant Lamps

GTI Graphic Technology, Inc.
For more information consult www.gtilite.com

Lamp Batch = **EOE**
If the third letter is "***E***", the lamp is ISO3664:2009 compliant. Lamps manufactured to the previous version of the Standard will show the letter "X" as the last character of the three digit code.

JUST Normlicht
For more information consult www.just.de/us



Lamp and package imprint notes:
ISO3664:2009

Other questions?

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