WI 160804.02

T 1212

DRAFT NO. 03 SARG

DATE October 5, 2021

WORKING GROUP CHAIRMAN Todd Popson

SUBJECT CATEGORY Optical Properties

RELATED METHODS See "Additional Information"

CAUTION:
This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

Light sources for evaluating papers including those containing fluorescent whitening agents (Five-year review of T 1212 sp-12)

(Suggested changes from previous Drafts incorporated)

1. Scope

1.1 This standard practice covers the significance and application of both instrumental and visual light sources for evaluating papers and related materials including those containing fluorescent whitening agents. The information presented is based on accepted proposals of the Inter Society Color Council (ISCC), Commission Internationale d'Eclairage (CIE), International Standards Organization (ISO), American National Standards Institute (ANSI), TAPPI, and TAPPI Optical Properties Committee experience. Also presented is a method for the visual evaluation of a color match under standard conditions of illumination.

1.2 The field of lighting is rapidly evolving with many advances in fluorescent and LED lighting. Primarily, the changes in LED lighting are causing change in industrial, retail and residential lighting

environments. The CIE (International Committee on Illumination) is researching and developing reports on the efficacy of LED's as light sources for evaluating materials including those containing fluorescent whitening agents. However, they have not issued any standards at this time. Also, the narrow bandwidth characteristic of existing LED's does not make them good representations of the traditional UV conditions used in the industry; as an example, illuminant A, C, D50, D65 and D75. Therefore, LED light sources are not covered in this standard.

2. Significance

2.1 Light sources are commonly described by their color temperature.

2.2 Common tungsten filament lamp color temperature is a very close approximation to the black body color temperature. These sources have a smooth and continuous spectral energy distribution. Non-black bodylight sources are described by their correlated color temperature which is the color temperature of a black body which they most closely resemble. Such sources are, for example, arc lamps whose spectral energy distributions are not continuous, but rather have concentrated energy in a few very narrow wavelength regions, or fluorescent lamps which do have continuous spectrums but superimposed with a few narrow wavelength regions of concentrated energy. In all cases, the spectral energy distribution for a light source at a given color temperature is defined in the visible portion only and does not include the amount or distribution of energy in the ultraviolet (UV) which excites fluorescent whitening or brightening agents. For these reasons, the description of a light source or an illuminant by giving the color temperature or correlated color temperature alone is not entirely satisfactory.

2.3 When viewing papers or related materials containing fluorescent whitening or brightening agents, the illumination must have a suitable form, must be continuous (not have significant energy located in a few spectral lines only), and must contain a sufficient amount of UV radiation to excite the fluorescent agent. The visual appearance of paper containing such an agent will depend on the relative amount of UV energy present in the illumination.

2.4 If only the presence of a fluorescent whitening agent in a material needs to be determined, then a light source rich in ultraviolet energy with only a very small amount of visible light should be used. A lamp such as Spectroline G-Series UV Lamp (365 nm) which operates on 115 V ac is suitable for this purpose. When a sample is viewed in the dark under such illumination, spot fluorescent contaminants can be distinguished from a uniform overall application of a fluorescent material.

3. Definitions

3.1 Definitions of technical terminology used in this standard practice may be found in TAPPI T 1213 "Optical Measurements Terminology (related to appearance evaluation of paper)."

4. Index of light sources

4.1 Table 1 is an index of light sources referred to in this document.

4.2 Specific light sources and illuminants

The applicable light sources are described by their approximate correlated color temperatures as follows:

4.2.1 2300-2854 K

4.2.1.1 The color of off-white papers may vary with the quality of the illuminant. To evaluate this effect, the specimen is viewed alternately under sources of low and high temperatures. Two low temperature illuminants have been in common use. One has a color temperature of 2300 K and is known as horizon light; the other is CIE Illuminant A which has a color temperature of 2854 K.

Table 1. Index of light sources.

Correlated color temperature, K	*Name of lamp*	*Manufacturer*	*Section*
(UV only)	-----	Ultra-violet Products	4.2.1
2300-2854	Tungsten filament	G. E. Sylvania, etc.	4.2.1
3000	ANSI Code CPR	G. E. PH/18AT 10P-6V	4.2.2
3000	No. 38 02 07	Carl Zeiss, Inc.	4.2.2
2800-3400	Tungsten-halogen	G. E. and Sylvania	4.2.2
3800	Avlite	GretagMacbeth	4.2.3
3800	Colorarc	Sylvania	4.2.3
4000-4200	Deluxe cool white fluorescent	Sylvania	4.2.4
5000	Macbeth 5000 fluorescent lamps in Prooflite D_{5000} System	GretagMacbeth	4.2.6
5000	Metalarc	Sylvania	4.2.6
5900	|XBO Xenon Arc	Osram	4.2.6
6000	Xenon Lamp in Elrepho Photometer	Zeiss	4.2.6
6500	Norlite D_{6500} Illumination systems	GretagMacbeth	4.2.7
6500	Osram Xenon XBF + filter	Osram	4.2.7
6500	Xenon lamp + filter in DMC 25 Spectrophotometer	Zeiss	4.2.7
6770	Illuminant C	--------	4.2.8
North Sky 7400	Macbeth Skylight Illumination System	GretagMacbeth	4.2.9
North Sky 7500	Macbeth Skylight Illumination System	GretagMacbeth	4.2.9
7500	Macbeth 7500 Fluorescent Lamps in Norlite D_{7500} System	GretagMacbeth	4.2.9

4.2.1.2 Two committees have adopted incandescent light at 2300 K (in conjunction with standard fluorescent light of 4400 K) as a standard for the detection of metamerism by visual viewing. ISCC Subcommittee for Problem 21 proposed 2300 ± 100 K with a Color Rendering Index (CIE *R*) = 92-100 in the Standard Practices for Visual

Examination of Small Color Differences. ASTM Committee D-1 for the revision of D-1729-64 also selected 2300 K with CIE R_a = 92-100 for Visual evaluation of Color Differences of Opaque Materials.

4.2.1.3 ASTM D-1729-60t specified a light source of 2854 K with tolerances of ± 100 K for an AA match or ± 75 K for an AAA match. In this method, the 2854 K source is augmented with a higher color temperature source, 7500 K and 7400 K respectively, for determining if a metameric match has been made.

4.2.1.4 The CIE official recommendations on colorimetry states that CIE Illuminant A represents the Planckian radiator (black body) at 2854 K and gives relative spectral power distribution from 380 to 780 nm. It is a standard source for instrumental determinations as well as visual viewing. Sources for 2300 K and 2854 K are calibrated gas-filled tungsten filament lamps operated at the proper conditions to give the specified color temperature.

4.2.2 3000 K

4.2.2.1 An incandescent source is used for most instrumental colorimetric work. The highest available color temperature is used in order to obtain the maximum available ultraviolet energy.

4.2.2.2 The relative spectral energy distributions of several nominal 3000 K sources used in instrumental work for the light incident on the specimen are shown in Fig. 1. The curves have been normalized to be equal to 100 at 500 nm. Many older Technidyne brightness and color testers use a quartz tungsten halogen (QTH) lamp, but with a heat absorbing filter. Many Hunter Color-Difference Meters likewise use a QTH lamp, a 6.9 mm (0.27 in.) thick Pittsburgh Plate Glass 2043 heat absorbing filter, and silicate-coated aluminum mirror which further reduces the relative amount of radiation above 600 nm. All of these sources provide essentially the same spectral energy distribution incident upon the specimen from 320 to 500 nm, but beyond this it varies as shown in Fig. 1.

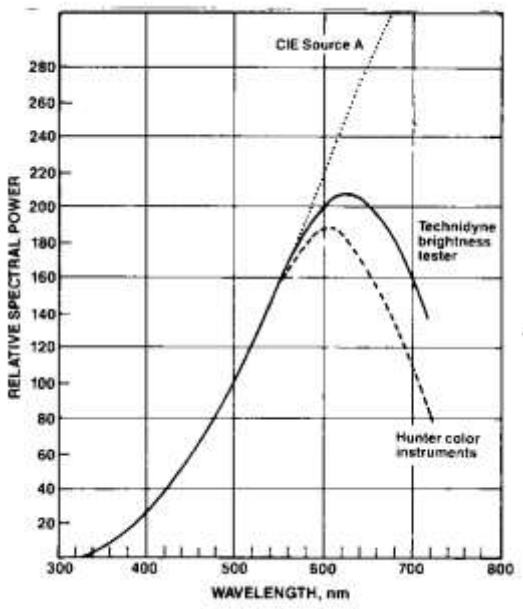

Fig. 1. Relative spectral energy distributions.

4.2.2.3 Quartz tungsten halogen (QTH) lamps contain a tungsten filament and halogen in a fused quartz

envelope. In the higher wattages, they can be operated at color temperatures as high as 3400 K and consequently emit slightly more ultraviolet radiation than standard glass envelope incandescent lamps, particularly since the quartz envelope will pass radiation down to 250 nm. The principal advantage of tungsten-halogen lamps is that the halogen combines with evaporated tungsten (vapor) and prevents it from being deposited on the inside of the lamp envelope, thereby eliminating blackening. This keeps the lamp clean, greatly increases its efficiency, and reduces changes in the intensity and spectral distribution of the radiation due to bulb blackening, thus permitting the use of the lamp until it burns out.

4.2.3 3800 K

4.2.3.1 This color temperature is used for visual viewing only. ANSI PH 2.23-1961, "American Standard Lighting Conditions for Viewing Photographic Color Prints and Transparencies," specified 3800 K.

4.2.3.2 Two light sources which approach the 3800 K source are the Macbeth Avlite and Sylvania Colorarc. The Avlite is a bipin fluorescent lamp available in several wattages. The Colorac is a mogul screw base iodide arc lamp available in several wattages.

4.2.4 4000 to 4200 K

The fluorescent lamps used in many color laboratories, office areas, and commercial establishments selected as a close quality match to natural daylight are the deluxe cool white lamps. The color rendering index for most manufacturer's lamps for a correlated color temperature of 4000 to 4200 K is approximately 86.

4.2.5 4400 K

The ISCC selected a color temperature of 4400 K for their standard fluorescent illumination in conjunction with 2854 K for detection of metamerism. See material included under light source 2300-2854 K for specific references to methods.

4.2.6 5000 K

4.2.6.1 In the graphic arts industries, standard illuminant D50 provides an average condition representing various aspects of actual use. When color matches are made at a low color temperature such as 3800 K or at a high color temperature such as 7500 K, the results are sometimes very poor when viewed under the opposite extreme. Skin tones, for example, which are most critical to the eye, may be a very poor match and not pleasing. D50 is an average of these extremes and has the most neutral spectral response of all standard daylight illuminants. The average office fluorescent light mixed with north sky daylight also falls near 5000 K. It probably is the best color temperature to represent average color viewing conditions but is known to overexcite optical brightening agents (OBAs) when present.

4.2.6.2 Macbeth Corporation manufactures GretagMacbeth Prooflite D50 Illumination Systems using 15- and 4-W GretagMacbeth 5000 Fluorescent Lamps. The correlated color temperature of these illumination systems is 5000 K.

4.2.6.3 Osram manufactures a unique XBO Xenon high pressure lamp. It has a relatively continuous spectrum in the visible range with little ultraviolet below 300 nm but has strong peaks in the infrared at 820, 900, and 980 nm.

The correlated color temperature of these lamps is approximately 5900 K. The lamp envelope is quartz and the discharge is the short arc type.

4.2.6.4 Sylvania manufactures a Metalarc lamp which is a high pressure mercury arc lamp but with the addition of a metal iodide to the mercury vapor. It has a correlated color temperature near 5000 K. The spectral distribution changes with ambient temperature.

4.2.7 6500 K

4.2.7.1 A color temperature of 5000 K is suited for appraising the color of most objects as viewed under average conditions. It does not, however, accentuate the difference between the yellowish tint of two near-white colors as well as one of 7500 K. A compromise between the two is 6500 K. When viewing optically brightened papers illuminant D65 may be used if the object of the evaluation is to accentuate the effect of fluorescent whitening agents, for color difference determination. **The use of D65 is discouraged**, however, when the object is to make comparisons in illumination similar to end use conditions, as D65 is known to overexcite optical brightening agents (OBAs) relative to visual assessment under end use conditions. Standard illuminant C more closely duplicates the spectral distribution of average office lighting particularly in the ultra-violet portion of the spectrum.

Table 2. Spectral power distribution of CIE Illuminant D65.

Wavelength, nm	*Relative power per unit wavelength*	*Wavelength, nm*	*Relative power per unit wavelength*
300	0.03	570	96.3
310	3.3	580	95.8
320	20.2	590	88.7
330	37.1	600	90.0
340	39.9	610	89.6
350	44.9	620	87.7
360	46.6	630	83.3
370	52.1	640	83.7
380	50.0	650	80.0
390	54.6	660	80.2
400	82.8	670	82.3
410	91.5	680	78.3
420	93.4	690	69.7
430	86.7	700	71.6
440	104.9	710	74.3
450	117.0	720	61.6
460	117.8	730	69.9
470	114.9	740	75.1
480	115.9	750	63.6
490	108.8	760	46.4
500	109.4	770	66.8
510	107.8	780	63.4
520	104.8	790	64.3
530	107.7	800	59.5
540	104.4	810	52.0
550	104.0	820	57.4
560	100.0	830	60.3

4.2.7.2 BSI Standard 950, Part 1-1967 for Illuminant for Colour Matching and Colour Appraisal specifies 6500 K and includes a UV range from 300 to 400 nm.

4.2.7.3 Macbeth Norlite D65 Illumination Systems will approximate this illuminant. Another recommended light source employs an Osram Xenon high pressure arc lamp XBF, 6000-W with quartz burner tube assembly, an

inner Pyrex filter glass and outer clear glass filter assembly, and a 5-mm heat absorbing Pittsburgh Glass No. l2403.

4.2.8 Standard Illuminant C is commonly employed in current spectrophotometers. In the visible region, Illuminant C is considered a daylight illuminant but in the UV region illuminant C simulates the UV level of average indoor lighting. No currently manufactured light booth offers Illuminant C.

4.2.9 7400 to 7500 K

4.2.9.1 Color temperatures of 7400 K and 7500 K have been the established standards where color differences are to be observed. However, with fluorescent whitening agents, a black body color temperature of 7500 K would accentuate the effect of the fluorescence beyond what would be observed under average visual conditions.

4.2.9.2 Macbeth Skylight Illumination Systems which produce North Sky 7400 K and 7500 K are available in a color matching unit with booth. Macbeth Norlite D7500 Illumination Systems using 15-and 4-W Macbeth 7500 Fluorescent Lamps meet the requirements of ASTM D 1729 for CIE D75.

4.3 Notes.

4.3.1 Some light sources are not suitable for color measurement work because of the deficiencies referred to under the General section. These include mercury, hydrogen, and deuterium lamps.

4.3.2 A hydrogen lamp, or more specifically, the direct current long arc in a hydrogen discharge lamp is the traditional ultraviolet source for spectral applications. The hydrogen is under pressure which causes the hydrogen lines to widen into almost continuous spectrum. These lamps are not adaptable, however, for color measurements with materials containing fluorescent whitening agents as the radiation does not extend into the visible portion of the spectrum.

4.3.3 Deuterium discharge lamps have spectral radiance distributions similar to hydrogen lamps, but they produce several times the intensity at comparable wattage. The continum is stronger and more expansive, but the radiation is limited to the UV portion of the spectrum.

4.4 Visual Evaluation Method

The routine visual evaluation of a color match may often be carried out satisfactorily under one light source and one set of illuminating and viewing conditions. For most satisfactory results, however, the color match *should be evaluated under the actual illuminating and viewing conditions of ultimate use.* This is particularly important when viewing optically brightened papers where a day-light source of illumination may over-excite the fluorescent brighteners in comparison to normal indoor lighting conditions.

5. Apparatus

5.1 *Illuminant.* The evaluation area comprises a suitable background and surround together with the necessary lighting units to provide the proper illuminant. “Illuminant” means the light incident on the specimen, not merely the flux emitted by the light source.

5.2 *Spectral power distribution.* CIE standard illuminant D65, namely reconstituted daylight having a correlated color temperature of 6500 K (1,2). It should have the relative spectral power distribution specified in Table

2 and the ultraviolet energy content and tolerances specified in Table 3. The target chromaticity coordinates are x = 0.3127; y = 0.3291. The tolerated area on the CIE chromaticity diagram is defined by lines connecting the 12 points whose coordinates are given in Table 4. Deviations from the actual spectral power distribution of the target illuminant for the visible portion of the spectrum are required to be such that the 1965 CIE General Color Rendering Index is over 90.

Table 3. Spectral distribution (2).

Spectral band	*Wavelength range, nm*	*Band value* for 100 lumen flux, mw*	*Tolerance in band value, %*
uv a	300-345	11.2	±30
uv b	345-375	18.8	±30
uv c	375-405	24.4	±30

*Radiant power flux when the luminous flux for the whole spectrum in some solid angle is 100 lumens.

5.3 *Photometric conditions.* For the general evaluation of papers of medium lightness, the illumination at the center of the viewed area is to be 807-1884 lumens/m^2 (75-175 footcandles) but for critical evaluation of such papers it is to be 1076-1345 lumens/m^2 (100-125 footcandles).

NOTE 1: For the evaluation of very light papers, the illumination may be reduced to as low as 538 lumens/m^2 (50 footcandles), and for very dark papers it may be increased to as high as 2153 lumens/m^2 (200 footcandles).

Table 4. CIE chromaticity coordinates of points bounding tolerance area for source.

x	*y*
0.3185	0.3383
0.3192	0.3361
0.3182	0.3320
0.3157	0.3272
0.3125	0.3228
0.3092	0.3202
0.3069	0.3199
0.3062	0.3221
0.3072	0.3262
0.3097	0.3310
0.3129	0.3354
0.3162	0.3380

5.4 *Geometric conditions.* Specimens are to be illuminated from an overhead extended-area source. The illumination over the viewing area should be uniform to within 20%, and abrupt changes in illumination level are not to be visible.

6. Background and surround

The viewing area is to be shielded from extraneous light, preferably by a permanent structure. The Munsell color characteristics of the background or table on which the specimens are placed and the surround or walls of the enclosure are described in Table 5. The gloss of the background and surround is not to exceed 30 as measured at 75° in TAPPI T 480 “Specular Gloss of Paper and Paperboard at 75°,” except that the background may be covered with paper of the type being examined.

Table 5. Color of background and surround.

Evaluation category	*Color surround**	*Color of background**	*Munsell Chroma of Neutrals, maximum*
Critical	N6 to N7	Similar to standard	0.2
General	N6 to N7	N5 to N7	0.3

*N5, N6, and N7 refer to neutral gray colors having a diffuse reflectance of 19, 30, and 44%, respectively.

7. Illumination meter

Suitable for measuring the illumination of the viewing area 538-2153 lumens/m^2 (50-200 footcandles).

8. Reference pad of the paper against which the specimens are compared

The pad is required to be at least 150 by 250 mm (6 x 10 in.) in size and thick enough to be opaque.

9. Test specimens

Obtain the sample in accordance with TAPPI T 400 “Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product.” Select specimens at least 150 x 250 mm (6 x 10 in.) in size, uniform in color and gloss, free from imperfections in surface texture, and free from fingerprints and other blemishes.

10. Procedure

10.1 Cover half the reference pad with a specimen and place both at the distance from the light source needed to obtain the required illumination. Use the illumination meter to determine the proper distance. Avoid any perceptible specular reflection of the light source by the specimen. If the source is directly overhead (preferred), place the specimen and reference pad horizontally and view them at an angle of 45 ± 5° from the perpendicular. Interchange the positions of the specimen and reference pad and reevaluate the difference. It is usually desirable to match the specimen under both the daylight source specified and an ordinary 100-W incandescent lamp having a color

temperature of 2854 K.

10.2 Observe the degrees of color difference between each specimen and the reference pad in terms of the hue, lightness, saturation, and overall match as follows:

(a) *Hue,* the attribute of color perception by means of which an object is judged to be red, yellow, green, blue, purple, or intermediate between some adjacent pair of these.

(b) *Lightness,* perception by which white objects are distinguished from gray, and light colored from dark colored.

(c) *Saturation,* quality of color sensation by which the observer is aware of different purities of any one hue.

(d) *Overall match,* expressed as "excellent," if much better than tolerance; "good," if definitely better than tolerance; "fair," if about as close as tolerance, and "poor," if worse than tolerance. For example, the difference between two red colors might be given as "moderately yellower (hue), slightly darker (lightness), very slightly grayer (saturation), overall match, fair."

11. Report

Include the following information as may be required:

A. *Type of evaluation,* approximate, general, or critical.

B. Description of the reference paper and the specimen, including their gloss and surface characteristics.

C. Intensity of illumination and direction of viewing.

D. Degree of color difference observed.

E. Any departures from the recommendations in this method.

F. Identity of the observer or a note as to his ability and experience.

12. Keywords

Light sources, Illumination, Paper, Fluorescent dyes, Ultraviolet radiation

13. Additional information

13.1 Effective date of issue: to be assigned.

13.2 Related methods: ASTM D1729, "Standard Practice for Visual Appraisal of Colors and Color Differences of Diffusely – Illuminated Opaque Materials," American Society for Testing and Materials, Philadelphia, PA; BS 950, Part 1, British Standards Institution, London, England.

13.3 This Standard Practice was formerly TIP 0804-01, revised in 1998.

References

1. Judd, D. B., MacAdam, D. L., Wyxzecki, G., "Spectral Distribution of Typical Daylight as a Function of Correlated Color Temperature," *J. Opt. Soc. Am.* 54:1031 (1964).
2. Wyszecki, G., "Development of New CIE Standard Sources for Colorimetry," *Die Farbe* 19: (1970 N. R. 1/6).

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department. ■