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BALLOT NO. _____ 04 SARG _____

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DATE _____ October 26, 2023 _____

WORKING GROUP
CHAIR _____ Nick Riggs _____

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 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.

Brightness of Pulp, Paper, and Paperboard (Directional Reflectance at 457 nm) (Early Review of Official Method T 452 om-18) (Underscores, notes, and strikethroughs show changes from Draft 2)

1. Scope

1.1 This method is for the determination of the brightness of white, ~~near-white~~near white, and naturally colored pulp, paper, and paperboard. Brightness is a commonly used industry term for the numerical value of the reflectance factor of a sample with respect to blue light of specific spectral and geometric characteristics. This method requires an instrument employing 45° illumination and 0° viewing geometry with the illuminating and viewing beams adjusted so that translucent materials are evaluated on an arbitrary but specific scale. The cone of light (see A.32.2 and A.32.5) used by this method is wider than that specified for the CIE Standard 45°/0° geometry.

1.2 Brightness and whiteness are not the same measurement. Brightness and whiteness are not interchangeable, and there is no known mathematical relationship between the two values.

1.3 This procedure is applicable to all ~~naturally-colored~~naturally colored pulps, and papers and board made therefrom and is suitable for optically brightened pulp and paper. The measurement is not suitable for paper or paperboard containing added coloring matter (such as yellow or green dyestuff) which appreciably absorbs light in that part of the spectrum extending from about 400 to 500 nm. This brightness method is not applicable to colored papers which must be measured either spectrophotometrically or colorimetrically ~~in order to~~to obtain meaningful results (1).

1.4 This method gives:

1.4.1 A procedure for using the test instrument to measure the directional reflectance factor at 457 nm of a sample of paper or paperboard (2-5).

NOTE 1: The effective wavelength of the spectral band is 457 nm. The shape of the function is also important as defined in Appendix A.

1.4.2 A description of a system ~~of for~~ preparing, distributing and using reflectance standards by which an instrument can be maintained in continuous agreement, to within specified tolerances, with a ~~master-primary reference~~ instrument.

1.4.3 A detailed description (Appendix A) of the significant spectral, geometric, and photometric characteristics of ~~an master-primary reference~~ instrument, with a statement of the tolerances which must be met in its construction and maintained during its use.

NOTE 2: It is possible that more than one primary reference instrument may be maintained to produce calibration standards and as part of the process of maintaining the brightness scale. All primary reference instruments must be manufactured to the same tolerances, within certain limits. It is generally expected that primary reference instruments are maintained to tighter tolerances than instruments manufactured for general use. (Primary reference instruments were formerly referred to as "master instruments.")

~~1.4.3~~

1.1.4 An optional procedure for separating the fluorescent component of brightness from the non-fluorescent component of brightness and measuring it quantitatively is described in Appendix C.

2. Summary of method

This method provides: (a) a scale for measurement of blue directional reflectance factor, (b) a method for verifying the calibration of each instrument used for reflectance testing so that the user can rely upon the test results, and (c) a means for determining the fluorescent component of brightness.

3. Significance

3.1 Blue-light reflectance measurements were originally designed to provide an indication of the amount of bleaching that has taken place in the manufacture of pulp. The higher the blue-light reflectance, generally the ~~whiter-brighter~~ the products will appear. The method provides a simple single-number index useful for comparing similar white materials; however, colored materials are better identified by using a standardized three-dimensional color space, see TAPPI T 524 "Color of Paper and Paperboard (45°/0° geometry)."

3.2 Because the instrument geometry of this method is different from that of TAPPI T 525 "Diffuse Brightness of Pulp (d/0)" and ISO 2470 "Measurement of Diffuse Blue Reflectance Factor (ISO Brightness)," there is no simple relationship between the two brightness scales (9, 10).

4. Reflectance scale and standards

4.1 *Reflectance scale:* The standard brightness scale is based on the reflectance of magnesium oxide of 100.0%. This scale is rigorously maintained utilizing instrumental methods not dependent upon unstable physical standards such as magnesium oxide (6).

4.2 *Calibration Standards:* Sets of paper tabs and a polished white ~~opal~~ glass standards¹ with calibration values based on ~~the master-primary reference instrument(s). Sets of at least five two pads of paper (one fluorescent and one non-fluorescent) of different reflectance levels and two one white opal~~ glass standards shall be provided.

4.3 Calibration Standards are to be provided by a calibration laboratory meeting the requirements of Section 5.3 of TAPPI T 1211 sp-01 "Acceptance Procedures for Calibration Laboratories."

5. Apparatus

5.1 *Brightness tester,* a test instrument which embodies the geometric, photometric and spectral characteristics specified in Appendix A and in such adjustment that its calibration is correct to within the tolerances specified in ~~6-1~~.

NOTE 3: ~~A~~ Agreement of the test instrument with the master instrument on one ~~or two~~ levels of standards is not sufficient proof that readings on the test instrument will agree with the master instrument throughout the range of application of this method. The test instrument will be in proper calibration if it reads all standards within ± 0.3 point of their assigned values.

5.2 *Standards,* a set of ~~five at least two~~ pads of paper ~~(one fluorescent and one non-fluorescent) tabs and one two~~ opal glass standards as described in 4.2, 7, and Appendix B.

5.2.5.3 *Black cavity,* for calibration of the zero point of the photometric scale. The black body shall have a reflectance factor which does not differ from its normal value by more than 0.2% at all wavelengths. The nominal value is usually zero.

B-
5.4 Backing weight, 1-kg weight with flat bottom.

¹Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list, available as part of the CD or printed set of Standards, or on the TAPPI website general Standards page.

6. Calibration

6.1 Calibration Standards

6.1.1 Reference Standard, a non-fluorescent white (paper) standard with certified traceability to the reflectance of magnesium oxide of 100.0%. These must be obtained from Calibration Laboratories.

NOTE 43: No known material is both perfectly reflecting and perfectly diffusing, but standards can be calibrated in terms of 100.0% reflectance of magnesium oxide.

6.1.2 Fluorescent Reflectance Standard, a fluorescent reference (paper) standard with certified UV excitation traceability based upon up-on CIE Illuminant C and CIE Standard Illuminant D65, to calibrate instruments for the measurement of fluorescent materials. These must be obtained from Calibration Laboratories.

6.1.3 Instrument (working) Standard, an opal glass instrument (working) standard is required.

NOTE 54: A paper reference standard is used to transfer calibration from a Calibration Laboratory to a given instrument. Reference standards should never be cleaned as cleaning may change their value. Instrument (working) standards should be used frequently to check the stability of a given instrument's calibration. An instrument (working) standard evaluated on from one instrument should never be used to calibrate another instrument. Instrument (working) standards may be cleanable (consult manufacturer's instruction manual).

6.2 Instrument Calibration

6.2.1 Follow the manufacturer's instructions to calibrate the instrument, using:

6.2.1.1 Black cavity for calibrating the zero point.

6.2.1.2 Reference Standard for calibrating the non-fluorescent scale.

6.2.1.3 Fluorescence Reflectance Standard for calibrating the fluorescent scale, and

6.2.1.4 Instrument (working) Standard for setting the transluceencytranslucency and storing a calibration value.

6.2.3 Obtain reflectance standards¹ at monthly intervals and calibrate the test instrument with them as soon as

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they are received. If the instrument readings on the standards differ from their assigned [brightness](#) value by more than ± 0.3 point, adjust the instrument in accordance with the manufacturer's instructions so that the readings agree with the assigned [brightness](#) values to within 0.3 point.

[6.26.4](#) Check the test instrument readings at least monthly against the assigned values of all the standards. A check should be made with the [Instrument \(working\) Standardopal glass standard](#) at least daily. The frequency of these checks will depend on the amount of use of the instrument and the accuracy required. Care should be exercised that the paper standards do not become soiled through frequent use.

[6.36.5](#) At intervals of ~~one to three~~[three months to one](#) years, depending upon the conditions and frequency of use, the test instrument should be carefully inspected, tested, and adjusted to ensure that its geometric and spectral characteristics fall within prescribed limits, and that its photometric system is within the specified tolerances.

7. Test specimens

7.1 Sample preparation—paper and paperboard

7.1.1 Sample the material to be tested in accordance with TAPPI T 400 “Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product.” From each test unit cut a representative portion of the paper or board into seven or more tabs at least 30 mm longer and 20 mm wider than the specimen aperture [nominally 51 mm (2 in.) by 38 mm (1½ in.) with the short dimension parallel to the machine direction]. Avoiding any water mark, dirt, or blemish, assemble the tabs in a pad with the felt (top) sides up. Use the top tab as a cover only; mark it near one corner to identify the sample and the top side. More than seven specimen tabs may be required for thin or transparent samples to ensure that the pad is completely opaque. (Only a few tabs will be required for paperboard.) The number of tabs in the pad should be such that the measured reflectance is not changed by doubling its thickness.

7.1.2 Do not touch test areas of the specimen with the fingers. Protect the test areas from contamination, excessive heat, or intense light.

[7.2](#) *Sample preparation—pulp.* Prepare sheets from pulp samples in accordance with TAPPI T 218 “Forming Handsheets for Reflectance Tests of Pulp (Büchner Funnel Procedure)” or TAPPI T 272 “Forming Handsheets for Reflectance Testing of Pulp (Sheet Machine Procedure).”

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8. Procedure

8.1 Without touching the test areas with the fingers, remove the protective cover tab and place it at the back of the pad. Place the pad over the specimen aperture of the instrument with the machine direction of the paper parallel to the plane determined by the axes of the incident and reflected rays of light and with the top side in contact with the instrument. If an orientation (“upstream/downstream”) effect is suspected (as in the case of some lightweight coated grades), rotate the pad 180° and observe the reading. If the difference between upstream and downstream brightness exceeds 0.3, clearly record in the report the reading for each orientation.

8.2 Place the 1-kg backing weight on the pad. Measure and record the reflectance reading to [0.01](#) unit. ~~Measurements performed on an instrument with a QTH bulb should be made within ten (10) seconds after placing the sample on the instrument. -within ten seconds after placing the pad on the instrument-~~

[8.3](#) Move the lower tab to the back of the pad and measure the second tab. Repeat this procedure until five tabs have been measured.

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8.3

~~NOTE 6:~~ [Temperature and moisture content of the specimens have a slight effect on brightness. The best reproducibility is obtained by conditioning and making the tests in an atmosphere of less than 60% +/- 5% relative humidity and a temperature of 23°C ± 14°C.](#)

9. Report

[9.1](#) Report the average brightness of the sample to ~~two~~[one](#) decimal places, together with the minimum and maximum readings. State clearly and conspicuously any deviations from the standard ~~procedure, and~~[procedure and](#) note any

unusual features or characteristics of the sample.

10. Precision

This would need to be updated.

10.1 Within lab repeatability and between lab reproducibility, as defined in TAPPI T 1200 "Interlaboratory Evaluation of Test Methods to Determine TAPPI Repeatability and Reproducibility," are estimates of the maximum difference (at 95% probability) which should be expected when comparing replicate measurements for materials similar to those described previously under similar test conditions. These estimates may not be valid for different materials or testing conditions.

10.2 In 2022 the Optical Properties Committee requested that a new precision study be conducted to reflect measurements made with spectrophotometer-based instruments using xenon flash lamps. The following precision estimates of repeatability and reproducibility from the 2022 (Table 1) study are based on data from ten laboratories using three different printing papers with ten specimens each,

NOTE 6: All precision testing prior to 2022 was performed with instruments using photocell or phototube instruments with quartz tungsten halide (QTH) lamps.

Where:

s_r	=	repeatability standard deviation
r	=	repeatability
s_n	=	between laboratory standard deviation
s_R	=	reproducibility standard deviation
R	=	reproducibility

Table 1. Results of 2022 precision study for spectrophotometer-based instruments.

Sample	Grand Mean	s_r	r	% r	s_n	s_R	R	% R
70# Text (0% Fluorescent Component)	73.60	0.043	0.120	0.20%	0.2	0.240	0.660	0.90%
80# Offset Text	102.30	0.049	0.135	0.10%	0.5	0.500	1.390	1.40%
80# Offset Text - UV Component	12.8	0.039	0.109	0.80%	0.4	0.37	1.030	8.00%
24# Multi-Purpose Office	92.80	0.091	0.253	0.3%	0.3	0.340	0.930	1.00%
24# Multi-Purpose Office - UV Component	6.40	0.049	0.136	2.1%	0.2	0.220	0.600	9.30%

10.3 The following estimates of repeatability and reproducibility were taken from the CTS Interlaboratory Program for Paper and Paperboard in 1996 and 1997 (Table 2.) Only labs using instruments using photocell or phototube instruments with QTH lamps were selected. For each sample, 55 to 61 laboratories are included in the statistics. Each estimate is based on eight determinations per sample.

Table 2. Results of 1996-1997 precision study for photocell and phototube instruments with QTH lamps.

Sample	UV Comp	Grand Mean	s_r	r	s_n	s_R	R
20# Bond	≈ 3%	83.1	0.220	0.61	0.650	0.682	1.89
50# Offset	≈ 3%	83.8	0.228	0.63	0.502	0.545	1.51
24# Bond	≈ 1%	84.7	0.128	0.35	0.630	0.641	1.78
96# Cover	≈ 4%	88.2	0.115	0.32	0.604	0.613	1.70

10.4 In 2014 the TAPPI Optical Properties Committee asked CTS to conduct a precision study to investigate how repeatability and reproducibility are affected by paper of very high brightness and fluorescent component. Three papers were utilized for the study and were tested by 11 select participating laboratories. The following estimates of repeatability and reproducibility were determined by CTS (each estimate is based on 30 readings per sample):

Table 3. Results of 2014 precision study for photocell and phototube instruments with QTH lamps.

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Sample	Grand Mean Brightness	S _r	r	%r	S _n	S _R	R	%R
RF01	90.38	0.1164	0.323	0.36%	0.290	0.294	0.816	0.90%
RF02	96.13	0.0553	0.153	0.16%	0.271	0.272	0.754	0.78%
RF03	98.78	0.0432	0.120	0.12%	0.291	0.292	0.808	0.82%

Sample	Grand Mean Fluorescent Component	S _r	r	%r	S _n	S _R	R	%R
RF01	7.42	0.077	0.214	2.88%	0.389	0.391	1.082	14.59%
RF02	9.12	0.029	0.079	0.87%	0.228	0.272	0.753	8.25%
RF03	8.21	0.040	0.111	1.35%	0.232	0.232	0.644	7.83%

The reader should be cautioned that these values are based on actual mill/laboratory brightness measurements with instruments or procedures which reportedly conform to the method. This information is given as a guide to the potential variation in directional brightness evaluation that may exist across the industry.

40.4 —

10.5

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11.10 Keywords

Brightness, Reflectance, Pulp, Paper, Paperboard, Fluorescence, Directional reflectance, Directional brightness

11.11 Additional Information

Effective date of issue: April 17, 2018 TBD 2023.

12.1

12.2 This method incorporates previous method TAPPI T 217 "Brightness of Pulp." This method was corrected in 1947 and revised in 1942, 1948, 1958, and withdrawn in 1977. It was reinstated in 1983, and revised in 1987, 1992, 1998, and 2002. The 2008 revision included an explanation of the difference between brightness and whiteness, and several editorial changes for clarification.

12.3.12.2 Related methods: Scandinavian SCAN P3:75, SCAN C11:75, SCAN G1:75, PAPTAC E.1; ISO 2469, 2470, and 3688. TAPPI T 525 "Diffuse Brightness of Pulp (d/0)," TAPPI T 534 "Brightness of Clay and Other Mineral Pigments (d/0 diffuse)," TAPPI T 646 "Brightness of Clay and Other Mineral Pigments (45/0)," TAPPI T 218 "Forming Handsheets for Reflectance Testing of Pulp (Büchner Funnel Procedure)," TAPPI T 272 "Forming Handsheets for Reflectance Testing of Pulp (Sheet Machine Procedure)."

12.4.12.3 Appendix C, Fluorescent component of brightness, was added in 1987.

12.4.12.4 A requirement to take the brightness reading within ten seconds after placing the sample pad on the instrument was added in 2018, to avoid any downward drift in brightness with papers containing fluorescent whitening agent.

12.5 A requirement for additional calibration paper standards was added in 2018, due to the market introduction of very high brightness (92 to 100%) papers containing high fluorescent component.

12.6 Also added in 2018 were the results of a new precision study utilizing papers of high brightness and fluorescent component.

12.2.12.7 In 2023, the method was updated to include the use of a spectrophotometer based instruments using a xenon flash lamp, detailed in Appendix A. Results of precision testing using spectrophotometer-based brightness testers were also included. Although the light source and detectors of instruments that conform to this revised method can be considered significantly different in a material sense, the instruments must still meet the requirements laid out in the appendices, therefore the test results should remain largely the same as other technologies. When transitioning to new instruments, users of this method should ensure that their requirements can continue to be met.^T

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Appendix A. Master instrument Brightness Tester

A.1 The ~~master Brightness Tester instrument~~ is defined by spectral, geometric, and photometric characteristics as follows:

A.2 ~~Spectral characteristics~~

A.3.0 The effective wavelength of the instrument, when used with the filter required for this standard is 457.0 ± 0.5 nm. The effective wavelength is that wavelength of monochromatic light for which the transmittance of a filter having a spectral transmittance given by the equation $T = a + b\lambda$ is equal to that determined with a master instrument, after a correction is made for effects associated with refraction and reflection, angular spread of rays through the filter, photometric error, and the wavelength error in the spectrophotometer employed to determine the spectral transmittance. In this equation, which need hold only for that wavelength range transmitted by the brightness filter, T is transmittance, a and b are constants, and λ is the wavelength. Filters having positive and negative b values should be employed so that, by averaging the two effective wavelength determinations, the correct effective wavelength will be obtained even though a photometric error may be present. Differences between the two values can be related to the photometric error which in the master instrument is not greater than 0.1%. A suitable correction should be applied if a photometric error exists. The spectral transmittance of the linear filter is measured relative to a clear, nonabsorbing plate of glass of equal thickness and similar index of refraction. The spectral transmittance is so measured in both the master instrument and the spectrophotometer, and the filters are so disposed with respect to apertures as to minimize error due to scattering of light in the filters and to make such error as may be due to light scattering the same in the master instrument and the spectrophotometer.

A.5.0 The spectral power distribution of the light incident on the specimen determines the response of the instrument to fluorescent radiation which may be caused by the presence of fluorescent whitening agents. The product of the spectral power distribution of the source and the spectral transmittance of the glass lenses and filter in the incident system is $E(\lambda)$, where $E(\lambda)$ is the function of wavelength given in Table 1.

Table 1. Relative spectral energy distribution of the light incident on the specimen.

<i>Wavelength</i>	<i>E(λ)</i>
<i>nm</i>	<i>relative units</i>
320	0.0
330	0.7
340	3.0
360	9.7
380	17.1
400	26.0
420	37.2
440	50.3
460	64.1
480	80.0
500	100.0

A.46.0 The effective wavelength, 457.0 ± 0.5 nm is obtained by the combination of illuminant, glass optics, filters, and photodetector for which the mathematical product of relative spectral power distribution, spectral transmittance, and spectral response is $F(\lambda)$, where $F(\lambda)$ is the function of wavelength given in Table 2. The area under the curve which represents the product for all wavelengths greater than 700 nm of the spectral sensitivity of the photoelectric cell, and the spectral transmittance of all filters between the specimen aperture and the photoelectric cell, is so small compared with a similar area for the wavelength range 360 to 510 nm that no detectable part of the photoelectric current may be ascribed to infrared fluorescence of the test specimen.

A.47A.2 Geometric characteristics

A.47.1A.2.1 The mean angle of incidence of light rays upon the test specimen is $45 \pm 0.5^\circ$.

A.47.2A.2.2 The incident rays upon a point of the test specimen are confined within a cone having a half angle of $11.5 \pm 2^\circ$. This cone is filled with light, has its vertex in the specimen aperture, and has its base at the emergent aperture of the condensing lenses.

A.47.3A.2.3 The specimen aperture is circular with a diameter of 12.7 ± 0.13 mm (0.500 ± 0.005 in.). The exit

aperture of the optical system which accepts reflected rays for measurement is concentric and parallel to the specimen aperture and has a diameter of 9.53 ± 0.076 mm (0.375 ± 0.003 in.) so that light reflected from the rim of the specimen aperture does not reach the ~~photoelectric cell~~ detector.

A.47.4 A.2.4 The mean angle of rays reflected by the test specimen and accepted by the receiving optical system for measurement is between 0° and 0.5° with the normal to the plane of the specimen aperture.

A.2.5 The reflected rays accepted for measurement are confined to a cone having a half angle of $22.5 \pm 2^\circ$.

NOTE 7: The geometric characteristics of brightness testers have not changed with this revision.

A.47.5

A.3 Photometric characteristics.

A.48 A.3.1 The instrument shall incorporate a photometric measurement system which measures reflectance in direct proportion to the light energy incident upon the sample within 0.43% throughout the entire range of measurement. Suitable checks must be made by the ~~manufacturer~~ standardizing laboratory to ensure the long-term stability of the spectral, geometric, and photometric characteristics of the ~~master~~ instrument.

A.4 Spectral characteristics.

A.4.1 The spectral distribution of the brightness function is shown in Table 1. This function has an effective wavelength of $457.0 \text{ nm} \pm 0.5 \text{ nm}$ with a bandpass at half peak height of 44 nm .

A.4.2 For a spectrophotometer or abridged ~~spectrophotometers~~ spectrophotometer, the spectral reflectance data obtained between 400 and 510 nm is to be integrated using the weighting function indicated in Table 1.

Table 1. Product of relative spectral power distribution of illuminant, spectral transmittance of glass optics, spectral transmittance of all filters and the spectral response of the detector ~~The relative spectral distribution function $F(\lambda)$ of a reflectometer equipment for measuring brightness.~~

<i>Wavelength, nm</i>	<i>F(λ), arbitrary units</i>	<i>δ nm weights</i>		<i>Wavelength, nm</i>	<i>F(λ), arbitrary units</i>	<i>δ nm weights</i>
400	1.0	0.107		460	100.0	10.668
405	2.9	0.309		465	99.3	10.593
410	6.7	0.715		470	88.7	9.462
415	12.1	1.291		475	72.5	7.734
420	18.2	1.942		480	53.1	5.665
425	25.8	2.752		485	34.0	3.627
430	34.5	3.680		490	20.3	2.166
435	44.9	4.790		495	11.1	1.184
440	57.6	6.145		500	5.6	0.597
445	70.0	7.467		505	2.2	0.235
450	82.5	8.801		510	0.3	0.032
455	94.1	10.038		Sum	937.4	100.000

Furthermore, the area under the curve of $F(\lambda)$ for wavelengths exceeding 700 nm should be small enough for the measurement not to be affected by any infrared fluorescent radiation generated in the sample.

Table 2. Product of relative spectral power distribution of illuminant, spectral transmittance of glass optics, spectral transmittance of all filters and the spectral response of the phototube (or photocell).

<i>Wavelength, nm</i>	<i>F(λ) relative units</i>
395	0.0
400	1.0
405	2.9
440	6.7

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415	12.1
420	18.2
425	25.8
430	34.5
435	44.9
440	57.6
445	70.0
450	82.5
455	94.1
460	100.0
465	99.3
470	88.7
475	72.5
480	53.1
485	34.0
490	20.3
495	11.1
500	5.6
505	2.2
510	0.3
515	0.0

Appendix B. Calibration service

C.2.1 A calibration laboratory may distribute standards monthly to all subscribers. A set of calibration standards shall comprise at least two pads of paper at R (one fluorescent and one non-fluorescent) and one white opal glass standard with brightness values accurately established by measurement on a primary reference instrument. Additional verification papers may be used to verify a broader spectral range (example: 50, 60, 70, 80, or 90% reflectance). The paper from which these standards are prepared shall be white, gray or cream colored, have a stable and uniform reflectance, and relatively smooth but not supercalendered surface.

A calibration laboratory will distribute standards on a monthly basis to all subscribers.

C.2.2 A set of calibration standards shall comprise at least two five pads of paper tabs (one fluorescent and one non fluorescent) and twone white opal glass standards with brightness values accurately established by measurement on a master instrument. More than one master instrument may be maintained by the calibration laboratory for the purpose of distributing calibration standards.

C.2.3 Additional verification The paper standards may be used to verify a broader spectral range (example: shall minimally cover a range from about 50, 60, 70, 80, or to 90% reflectance). The paper from which these standards are prepared shall be white, gray or cream colored, have a fairly stable and uniform reflectance, and a

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~~relatively smooth but not supercalendered surface. At least one standard in the 50 to 90% reflectance range containing a fluorescent whitening agent shall be employed for calibration if optically brightened papers are to be measured. If the optically brightened papers to be measured have a brightness above 92%, the calibration service shall also include a standard of minimum 96% brightness with a fluorescent component of at least six percentage points. This additional standard shall be used to calibrate the instrument.~~

~~C.2.7C.2.2~~ The opal glass standards shall have a surface not deviating from a true plane by more than 0.025 mm (0.001 in.). The nature of the surface polish and hardness and the optical stability of the material shall be such that the reflectance during one month of intensive but careful use will not vary more than 0.2 point, and such that it may be easily and effectively cleaned and be sufficiently resistant to withstand several cleanings per day. The color of the opal glass standards shall be white with the maximum spectral reflectance not to exceed 25% more than the minimum over the wavelength range of 400 to 500 nm. The opal glass standards shall be non-fluorescent (i.e., <0.20 fluorescent component on a %).

Appendix C. Fluorescent component of brightness

C.1 Scope and significance

C.1.1 The purpose of the procedure in this appendix is to describe a method for separating the fluorescent component of brightness from the non-fluorescent component and measuring it quantitatively.

C.1.2 When brightness is measured in accordance with the procedures outlined in this method, the specimen is illuminated with a broad spectrum of light, and the blue reflectance is measured. If the material contains natural or added fluorescent brighteners, a higher brightness reading will be obtained than if no fluorescence were present. The brightness reading, therefore, includes a "non-fluorescent component" and a "fluorescent component."

C.1.3 Fluorescence is excited when radiation of short wavelength (often ultraviolet, violet, and blue light) is partially absorbed in a process that yields visible light or infrared radiation. If no short wavelength light strikes the specimen, no fluorescence in the blue region of the spectrum is excited. The appropriateness of the effective ratio of UV light to blue light of the spectrum described in Table 1 was challenged within the Optical Properties Committee in 1989. A series of studies involving brightness and whiteness measurements and subjective ratings using different UV: blue light ratios showed that the spectrum was, indeed, representative of a typical office. This is desirable since paper is used almost exclusively indoors (8).

C.1.4 Figure 1 shows a simplified diagram of the illumination and viewing system of a brightness tester in its normal configuration. Ultraviolet and visible light are allowed to illuminate the specimen, and reflected light is passed through the brightness (blue) filter before striking the ~~spectrometerphotocell~~. The brightness reading, therefore, includes the visible blue light reflected by the specimen, plus additional blue light which was excited by the ultraviolet light in the incident beam.

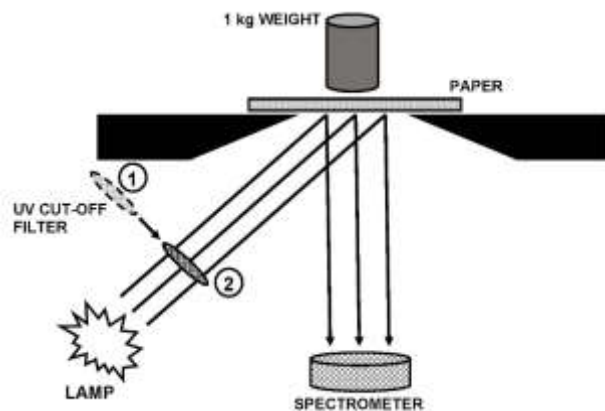
C.1.5 ~~If a sharp cut-off UV-absorbing filter is used to remove the UV energy of the incident~~ ~~The brightness filter, referred to in C.1.4, consists of several component filters placed together. If the ultraviolet absorbing component of the brightness filter has been moved from the reflected beam to the incident beam (Fig. 21),~~ the overall spectral response of the instrument (Table 1) remains unchanged, but it prevents the passage of ultraviolet light and allows only the visible blue light to illuminate the specimen and reflect into the ~~spectrometerphotocell~~. If no fluorescence is present, the brightness reading will be the same regardless of whether the ~~UV-absorbing filter is deployed~~ ~~ultraviolet absorbing component of the filter is~~ in the incident beam or ~~not the reflected beam~~. If fluorescence is present, the readings will differ; the difference being the amount of light contributed by the "fluorescent component." For example, if a brightness reading of 90.0 is obtained using the normal configuration, ~~filter position 1~~ in Fig. 1, and a brightness of 85.0 is obtained using the ~~filter position 2~~ in Fig. 21 configuration, then the "fluorescent component" is equal to 5.0 or 5 "brightness points."

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**FIGURE 1 – Optics for fluorescence inclusion (filter position 1)
 and for fluorescence exclusion (filter position 2).
 Note: Some brightness testers use a photocell instead of a spectrometer.**

C.2 Ultraviolet adjustment.

C.2.1 For the measurement of materials containing fluorescent whitening agents, some means of setting the spectral power distribution of the radiation incident on the test piece to give a specified UV content within the spectral range defined by the CIE and of maintaining this setting or of mathematically simulating such a power distribution is required. For this purpose, a filter having a half-peak cut-off wavelength of 395 nm shall be used. If the filter is movable, it shall be mounted in a device which permits its position to be identified and maintained, and reproducibly reset. In addition, a filter or other means shall be provided to reduce the impact of UV-B excitation on the measurements. For this purpose, a sharp cut-off filter with a maximum transmission of 50% at 320 nm shall be used.

NOTE 6: The relative spectral power distributions of the CIE illuminants C, D50, and D65 are defined only for wavelengths longer than 300 nm.

C.3 Fluorescence elimination.

C.3.1 For the measurement of radiance factors with the fluorescence effect eliminated, the instrument shall be equipped with a sharp cut-off UV-absorbing filter having a transmittance not exceeding 5% at and below a wavelength of 410 nm and exceeding 50% at a wavelength of 420 nm (i.e., a half-peak cut-off wavelength of 420 nm), or shall employ an equivalent procedure.

C.3.2 The cut-off filter shall have characteristics such that a reliable radiance factor value is obtained at 420 nm. This value shall be repeated at all lower wavelengths to provide adequate data for the colorimetric computations.

NOTE 7: —This procedure is equivalent to the ASTM E308 06 instruction to add the weighting functions if data for certain wavelengths are

C.2 —Apparatus. Brightness tester, a test instrument as described in 4.1 and equipped with fluorescence separation capability and in such adjustment that it correctly measures the fluorescent component of the paper standard provided by a standardizing laboratory within ± 0.3 brightness units. Refer to section B.2 for calibration information. Other criteria are: