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An American National Standard

Standard Test Method for Brightness of Pulp, Paper, and Paperboard (Directional Reflectance at 457 nm)[1]

This standard is issued under the fixed designation D 985; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method determines the brightness of 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 test 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 **(1-4)**.[2]

1.2 This test method is applicable to all naturally-colored pulps, and papers and board made from pulps. The measurement is not suitable for paper and 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. Colored papers must be measured spectrophotometrically or colorimetrically in order to obtain meaningful results (TAPPI T442, T524, and T527). This test method is, however, suitable for pulps or papers which contain optical (fluorescent) brightening agents.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, and Related Products[3]

D 1968 Terminology Relating to Paper and Paper Products[3]

2.2 *TAPPI Standards:*

T 218 Forming handsheets for reflectance tests of pulp[4]

T 442 Spectral reflectance factor, transmittance and color of paper and pulp (Polychromatic illumination)[4]

T 452 Brightness of pulp, paper and paperboard (Directional reflectance of 457 nm)[4]

T 524 Color of white and near-white paper and paperboard by *L, a, b* 45° 0° colorimetry[4]

T 527 Color of paper and paperboard in CIE system[4]

T 1206 Precision statements for test methods[4]

3. Terminology

3.1 *Definitions*—Definitions shall be in accordance with Terminology D 1968 and the *Dictionary of Paper.*[4]

4. Summary of Test Method

4.1 This test method provides the following:

4.1.1 A scale for measurement of paper brightness (blue directional reflectance factor),

4.1.2 A method for verifying the calibration of each instrument used for brightness testing so that the user can rely upon the test results, and

4.1.3 Criteria for the geometric, and photometric characteristics required by instruments employed in the use of this test method.

4.2 A procedure is also described for separating the fluorescent component of brightness from the non-fluorescent component of brightness and measuring it quantitatively.

5. Significance and Use

5.1 Brightness is the most extensively used optical property of pulp, paper, and paperboard. The measurement of brightness (blue reflectance) was originally devised as a means of quantitatively assessing the effectiveness of pulp bleaching. A specific spectral response has been defined and rigorously maintained, providing long–term stability of brightness values to the industry.

5.2 The accurate determination of brightness is of vital importance in the buy-sell relationship between the paper producer and consumer. High brightness is an indication of

[1] This test method is under the jurisdiction of ASTM Committee D06 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Test Methods.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] *Annual Book of ASTM Standards*, Vol 15.09.

[4] Available from the Technical Association of the Pulp and Paper Industry, P.O. Box 105113, Atlanta, GA 30348.

high-quality paper, resulting in a price structure where price is relatively proportional to the brightness level. Paper producers are required to employ additional bleaching or the addition of costly optical brighteners in order to obtain high-brightness paper. The high cost of such brightening materials mandates adherence to close production tolerances for the brightness of the end product.

6. Apparatus

6.1 *Brightness Tester*—A test instrument which embodies the geometric and spectral characteristics specified in Annex A1 and in such adjustment that its calibration is correct within the tolerances specified in Section 8.

6.2 *Standards*—A set of five pads of paper sheets and two opal glass standards as described in Section 8 and Annex A3.[5]

6.3 *Backing Weight*, 1-kg weight with flat bottom (used with top loading instrument).

7. Sampling and Test Specimens

7.1 *Sample Preparation*:

7.1.1 *Paper and Paperboard*:

7.1.1.1 Sample the material to be tested in accordance with Practice D 585. From each test unit, cut a representative portion of the paper or board into seven or more sheets at least 37 by 50 mm (1½ by 2 in.) with the short dimension parallel to the machine direction. Avoiding any watermark, dirt, or blemish, assemble the sheets in a pad with the top sides up. Using the top sheet as a cover only, mark it near one corner to identify the sample and the top side. More than seven specimen sheets may be required for thin or transparent samples to ensure that the pad is completely opaque. (Only a few sheets will be required for paperboard.) The number of sheets in the pad should be such that the measured reflectance is not changed by doubling the number of sheets.

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

7.1.2 *Pulp*—Prepare sheets from pulp samples in accordance with TAPPI T 218.

8. Calibration

8.1 Obtain a set of paper and opal glass standards at monthly intervals. Calibrate the test instrument in accordance with manufacturers' instructions, to the assigned values of a mid-range paper tab and an opal glass standard.

8.2 Check the test instrument readings against the assigned values of all five paper pads and two opal glass standards. If the instrument reading on any individual paper pad or opal glass standard differs from the respective assigned value by more than ±0.3 brightness points, adjust the instrument in accordance with the manufacturer's instructions so that the readings agree to within 0.3 brightness points.

8.2.1 The brightness value for a paper pad is the average of brightness values obtained for the five sheets under the cover sheet. The cover sheet is not to be measured.

8.3 Check the test instrument readings at least monthly against the assigned values of five paper tabs and two opal glass standards. A check should be made with one of the opal glass standards 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.

8.4 At intervals of six months to two 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 to within prescribed limits, and that its photometric system is within the specified tolerances.

9. Conditioning

9.1 Preconditioning of test specimens for this test method is not normally required.

10. Procedure

10.1 *Measuring Brightness*:

10.1.1 Place the filter selector in the *brightness* position.

10.1.2 Without touching the test areas with the fingers, remove the protective cover sheet 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 axis of the incident and reflected rays of light and with the top side in contact with the instrument. If an orientation effect is suspected (as in testing of creped or embossed specimens), rotate the pad and observe the highest and lowest readings. Clearly record in the report how the specimens are oriented and the reading for each orientation.

10.1.3 Place the 1-kg backing weight on the pad or clamp the pad in place with the specimen clamp. Measure and record the brightness reading to at least 0.1 % reflectance.

10.1.4 Move the sheet just measured to the back of the pad and measure the second sheet while being backed by the pad. Repeat this procedure until five sheets have been measured. Average the five readings.

10.2 *Measuring Fluorescent Component of Brightness*:

10.2.1 Set the filter selector to the *fluorescence* position.

10.2.2 Place the opal glass standard over the specimen aperture and, if necessary, adjust to the standard value.

10.2.3 Place the specimen over the specimen aperture as described in 10.1.2. Measure and record the brightness readings for five sheets and average the five readings as described in 10.1.3 and 10.1.4.

10.2.4 Calculate the fluorescent component by subtracting the value obtained in 10.2.3 from the value obtained in 10.1.4.

NOTE 1—Some instruments automatically measure fluorescent component of brightness.

11. Report

11.1 Report the average brightness of the sample to one decimal place together with the minimum and maximum readings. State clearly and conspicuously any deviations from the standard procedure, and note any unusual features or characteristics of the sample.

[5] Available from The Institute of Paper Science & Technology, P.O. Box 105113, Atlanta, GA 30348, and Technidyne Corporation, 100 Quality Ave., New Albany, IN 47150.

12. Precision and Bias

12.1 The following values were derived from Reports 131 through 135 of the *Paper and Paperboard Collaborative Reference Program*.[6] The directional brightness of the paper samples evaluated ranged from 79 to 88 %. Eight test determinations were made per sample and approximately 60 laboratories participated. The terms repeatability and reproducibility are used as defined in TAPPI T 1206.

Grand Mean	Repeatability	Reproducibility
79.93	0.42	1.52
82.96	0.61	1.96
87.55	0.53	1.68

[6] Conducted by Collaborative Testing Services, Inc.

12.2 The user of this precision data is advised that it is based on actual mill testing or laboratory testing, or both. There is no knowledge of the exact degree to which personnel skills or equipment were optimized during its generation. The precision quoted provides an estimate of typical variation in test results which may be encountered when this test method is routinely used by two or more parties.

12.3 The procedure in this test method has no bias because the value of brightness is defined only in terms of the test method.

13. Keywords

13.1 brightness; directional reflectance; fluorescence; fluorescent component; opal glass standards; optical brighteners; photometric; spectral

ANNEXES

(Mandatory Information)

A1. SPECTRAL, GEOMETRIC, AND PHOTOMETRIC CHARACTERISTICS OF INSTRUMENT

A1.1 *Spectral Characteristics*—The effective wavelength of the instrument, when used with the filter required for this test method 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 equal thickness and similar index of refraction. The spectral transmittance is so measured in both the master instruments and the spectrophotometer, 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.

A1.1.1 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 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 A1.1.

A1.1.2 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 A1.2. 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 from 395 to 515 nm that no detectable part of the photoelectric current may be ascribed to infrared fluorescence of the test specimen.

A1.2 *Geometric Characteristics*—The mean angle of incidence of light rays upon the test specimen is 45 ± 0.5°.

A1.2.1 The incident rays upon a point of the test specimen are confined within a cone having a half angle of 11.5 ± 2°.

TABLE A1.1 Relative Spectral Energy Distribution of Light Incident on Specimen

NOTE 1—Color temperature of the light source is 2800 ± 100 K.

Wavelength, nm	E(λ), relative units
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

TABLE A1.2 Product of Relative Spectral Power Distribution of Illuminant, Spectral Transmittance of Glass Optics, Spectral Transmittance of all Filters, and the Spectral Response of the Photocell

Wavelength, nm	F(λ), relative units
395	0.0
400	1.0
405	2.9
410	6.7
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

This cone is filled with light, the vertex is in the specimen aperture, and the base is at the emergent aperture of the condensing lenses.

A1.2.2 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 photocell.

A1.2.3 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.

A1.2.4 The reflected rays accepted for measurement are confined to a cone having a half angle of 22.5 ± 2°.

A1.3 *Photometric Characteristics*—The instrument incorporates a photometric measurement system which measures reflectance in direct proportion to the light energy incident upon the sample within 0.1 % throughout the entire range of measurement. Suitable checks must be made to ensure the long-term stability of the spectral, geometric, and photometric characteristics of the master instrument.

A2. CALIBRATION SERVICE

A2.1 The brightness scale is based on the reflectance of magnesium oxide of 100.0. The relationship between the reflectance of magnesium oxide and that of the perfect reflecting diffuser has been established. The establishment of this relationship allows the use of instrumental methods of calibration that do not require the use of magnesium oxide, which is optically unstable (6).

A2.2 A standardizing laboratory will distribute standards on a monthly basis to all subscribers. A set of standards will comprise at least five pads of paper sheets and two white opal glass standards with brightness values accurately established by measurement on the master instrument at the standardizing laboratory.

A2.3 The paper standards will cover a range from about 50 to 90 % reflectance. The paper from which these standards are prepared will be white or cream colored, have a fairly stable and uniform reflectance and a relatively smooth but not supercalendared surface. At least one standard containing a fluorescent whitening agent should be employed for calibration if optically brightened papers are to be measured.

A2.4 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 brightness points. The material should be easily and effectively cleaned and be sufficiently resistant to withstand several cleanings a day. The opal glass standards shall be white and non-fluorescent, with the maximum spectral reflectance not more than twice the minimum over the wavelength range from 400 to 500 nm.

A2.5 Clean the opal glass standards using a solution of 0.3 % nitric acid, 80 % ethyl alcohol, and 19.7 % distilled water.

A3. FLUORESCENT COMPONENT OF BRIGHTNESS

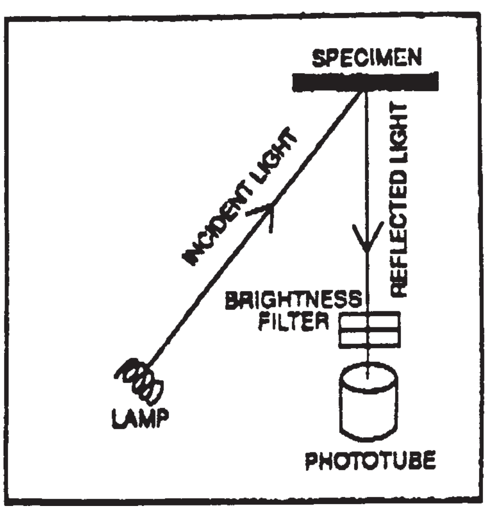
A3.1 The purpose of this annex is to describe a method for separating the fluorescent component of brightness from the non-fluorescent component and measuring it quantitatively.

A3.2 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."

A3.3 Fluorescence is stimulated when radiation of short wavelength (often ultraviolet, violet, and blue light) is partially absorbed in a process that yields visible light. If no short wavelength light strikes the specimen, no fluorescence in the blue region of the spectrum is excited.

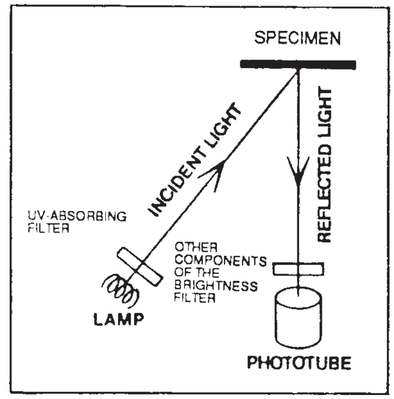
A3.4 Fig. A3.1 shows a simplified diagram of the illumination and viewing system of a brightness tester in its normal configuration. Ultraviolet and visible light are allowed to illuminate the specimen, and reflected light is passed through the brightness (blue) filter before striking the photocell. The brightness reading includes the visible blue light reflected by the specimen, plus additional blue light which was excited by the ultraviolet light in the incident beam.

A3.5 The brightness filter, referred to in A3.4, 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. A3.2), the overall spectral response of the instrument (Table A3.1) 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 photocell. If no fluorescence is present, the brightness reading will be the same regardless of whether the ultraviolet absorbing component of the filter is in the incident beam or 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 in Fig. A3.1 and a brightness of 85.0 is obtained using the Fig. A3.2 configuration, then the "fluorescent component" is equal to 5.0 or 5 "brightness points."



NOTE 1—Fluorescence is excited and read if present.

FIG. A3.1 Normal Configuration for Brightness Measurement



NOTE 1—Ultraviolet illumination of the specimen is eliminated.

NOTE 2—Fluorescence is not excited and only the "non-fluorescent" component of brightness is read.

FIG. A3.2 UV-Absorbing Component of Brightness Filter Moved to Incident Beam

TABLE A3.1 Relative Spectral Energy Distribution of Light Incident on Specimen with UV Absorbing Filter in Incident Light Beam (Fig. A3.2)

Wavelength, nm	F(λ), relative units
380	0.0
400	1.0
420	8.2
440	22.4
460	45.3
480	71.7
500	100.0

A3.6 The brightness tester includes filters which must be selected so that the effective wavelength of the overall brightness function (Table A1.2) does not change more than ±1.5 nm when the UV absorbing filter is moved from the receiving to the incident light beam. Likewise the bandwidth must not change more than± 3 nm under the same conditions.

A3.7 The instrument response in the red (600–700 nm) region of the spectrum must not exceed 0.2 reflectance units.

A3.8 The "fluorescent component" measured on the nonfluorescent paper and opal glass standards must not exceed 0.2 brightness units.

A3.9 For non-fluorescent paper, the measured brightness is independent of the light source. This does not hold for specimens containing optical brighteners as the degree of fluorescence excitation is directly related to the spectral energy distribution of the light incident upon the specimen. The relative spectral energy distribution of the light incident on the specimen will be changed from that shown in Table A1.1 to that shown in Table A3.1 by the movement of the UV absorbing filter from the receiving to the incident beam. The spectral distribution of the energy incident upon the specimen must be sufficiently matched to that shown in Table A3.1 to correctly measure the fluorescent paper standard provided by the standardizing laboratory **(5)** within ±0.5 brightness units.

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(**1**) Instrumentation Studies XIII, *Paper Trade Journal* 104 (18):47; (19):51; (20):45 (1937); XX, *Paper Trade Journal* 105 (18):134; (19):27 (1937); XXI, *Paper Trade Journal* 105 (25):46 (1937); XXII, *Paper Trade Journal*105 (27):42 (1937); XVIII, *Paper Trade Journal* 107 (20):33 (1938); XXIX, *Paper Trade Journal* 107 (25):29 (1938); XXXVII, *Paper Trade Journal* 112 (1):13 (1941); LVIII, *Tappi* 33 (10):85 (1950); LXV, *Tappi* 34 (9):143A (1951); LXIV, *Tappi* 34 (8):126A (1951); LXXVI, *Tappi* 35 (11):141A (1952); LXXXIV, *Tappi* 41 (9):196A (1958); LXXXV, *Tappi* 43 (2):230A (1950); LXXXVI, *Tappi* 43 (5):253A (1960); LXXXVII, *Tappi* 46 (1):179A (1963); Van den Akker, J.A., Nolan, P., and Wink, W. A. "The Physical Basis of Standardization of Brightness Measurement," *Paper Trade Journal* 114 (5):34 (1942); Van den Akker, J.A. "Wavelength Calibration of Spectrophotometers," *Journal of the Optical Society of America* 33 (5):257 (1943).

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