

T 525 om-12

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Diffuse brightness of paper, paperboard and pulp ($d/0$) – ultraviolet level C

1. Scope

1.1 This method is for the determination of 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 method requires an instrument employing diffuse illumination and 0° viewing geometry

1.2 This method is applicable to all naturally-colored pulps, and papers and board made therefrom. 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.

1.3 Pulps to be tested shall be made into handsheets prepared according to TAPPI T 218 "Forming Handsheets for Reflectance Tests of Pulp (Büchner Funnel Procedure)" or T 272 "Forming Handsheets for Reflectance Tests of Pulp (Sheet Machine Procedure)." This method can also be used to measure the brightness of machine-dried sheets.

NOTE 1: The brightness of a handsheet will usually be 0.5 to 1.0 units higher than that of a machine-dried sheet made from the same pulp.

1.4 This method utilizes an integrating sphere to provide diffuse illumination and perpendicular (0°) observation geometry (1) designated in optical terminology as $d/0$. With this geometry, specimen surface structure and azimuthal orientation have a negligible effect on brightness.

1.5 The instrument has a relatively large specimen aperture for the purpose of averaging small area variations in reflectance, making it possible to obtain a reliable average value with only a few individual measurements.

1.6 This method is not intended for use with colored materials.

Approved by the Standard Specific Interest Group for this Test Method



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2. Summary

Diffuse reflectance is measured in the wavelength range of 400-520 nm with an effective wavelength of 457 nm by using a suitable filter set or an equivalent device for modifying the spectral response and an instrument having diffuse illumination and perpendicular observation geometry. The measurements are made in terms of absolute reflectance factors.

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 the products will appear. In recent years, the method has been extended to white and near-white paper and paperboard, and is suitable for that purpose. 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)" and T 527 "Color of Paper and Paperboard (d/0 Geometry)"].

3.2 Because the instrument geometry of this method is different from that of TAPPI T 452 "Brightness of Pulp, Paper and Paperboard (Directional Reflectance at 457 nm)," there is no simple relationship between the two brightness scales (3).

3.3 Specularly reflected light (gloss) is excluded from the measurement of diffuse brightness by the use of a gloss trap (specular reflectance absorber) as required in 5.1.1.3.

NOTE 2: Material containing fluorescent brightening agents will exhibit higher reflectance values to a degree which is dependent upon the ultraviolet (UV) content of the radiation incident on the specimen. Control of such UV content is essential to maintain continuity of measurement among optically brightened pulps. This method specifies that the level of UV excitation correspond to the equivalent level of CIE Illuminant C.

NOTE 3: No known material is both perfectly reflecting and perfectly diffusing, but standards can be calibrated in terms of absolute reflectance factors (2,4). Standards with calibrations based on this reference can be obtained from Calibration Laboratories¹, as defined in Section 5.3 of TAPPI T 1211 "Acceptance Procedures for Calibration Laboratories."

4. Definitions

4.1 *Diffuse reflectance factor*, the ratio of the radiance factor of a specimen to that of a perfectly reflecting diffuser, each being irradiated and viewed identically (4).

4.2 *Absolute brightness*, the diffuse reflectance factor for blue light in terms of a perfectly reflecting, perfectly diffusing specimen as determined on an instrument as described in Section 5.

4.3 *Perfect reflecting diffuser*, the ideal reflecting surface that neither absorbs nor transmits light, but reflects diffusely, with the radiance of the reflecting surface being the same for all reflecting angles, regardless of the angular distribution of the incident light.

5. Apparatus

5.1 *Reflectometer*¹, an instrument designed for the measurement of diffuse reflectance which employs the following geometric, photometric, and spectral characteristics:

5.1.1 *Geometric characteristics*

5.1.1.1 One or more light sources direct light into an integrating sphere which provides diffuse illumination of the specimen. The integrating sphere has an inside diameter of 150 mm and is coated with a matte white paint with absolute reflectance of 96 or greater from the light source. The sphere shall be equipped with screens to eliminate direct illumination of the specimen.

5.1.1.2 The sum total of the areas of the apertures and other non-reflecting areas in the sphere does not exceed 13% of the area of the inner surface of the sphere.

5.1.1.3 The receptor aperture is surrounded by a gloss trap (black circular area) of external diameter subtending a half-angle of $15.5 \pm 0.5^\circ$ at the center of the specimen aperture.

¹ Names 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.

- 5.1.1.4 No light reflected from the rim of the specimen aperture shall reach the receptor.
- 5.1.1.5 The measured test area on the specimen is circular with a diameter of $28 \text{ mm} \pm 2 \text{ mm}$.
- 5.1.1.6 The specimen aperture diameter shall be $34 \text{ mm} \pm 1 \text{ mm}$ and the edge thickness shall not exceed 1.5 mm.
- 5.1.1.7 The specimen is viewed perpendicularly (0°). Only reflected rays within a solid cone, whose vertex is in the center of the specimen aperture and of half-angle not greater than 4° , shall fall on the receptor.
- 5.1.1.8 Stray light from all sources shall not exceed 0.5%.
- 5.1.2 *Photometric characteristics.* The accuracy of the photometer, whether mechanical or electronic, is such that the departure from photometric linearity after calibration does not exceed 0.3% reflectance factor.
- 5.1.3 *Spectral characteristics.* 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. In a filter based reflectometer this spectral distribution is the product of the following variables:

- the relative spectral distribution of the reflectance of the integrating sphere,
- the spectral transmittance of the glass optics,
- the spectral transmittance of the filters, and
- the spectral response of the photoelectric cell(s).

For a spectrophotometer or abridged 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. The relative spectral distribution function $F(\lambda)$ of a reflectometer equipment for measuring diffuse brightness.

Wavelength, nm	$F(\lambda)$, arbitrary units	5 nm weights		Wavelength, nm	$F(\lambda)$, arbitrary units	5 nm weights
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.

- 5.1.4 *Spectral radiance control:* The instrument shall have some means of controlling the ultraviolet spectral radiance of the light entering the sphere and thus irradiating the sample (see Appendix A.1).
- 5.2 The following ancillary items must be available:
- 5.2.1 Reference standards, a non-fluorescent, white standard with a brightness calibration value with traceability to the perfect reflecting diffuser. If the instrument is to be calibrated for the measurement of fluorescent materials, a white fluorescent reference standard with traceability for CIE C standard illuminant conditions must be used.
- 5.2.2 *Instrument standard(s)*, one or more opal glass or ceramic standards.
- 5.2.3 *Black cavity*, for calibration of the zero point of the photometric scale. This black body shall have a reflectance factor which does not differ from its nominal value by more than 0.2% at all wavelengths. The nominal value is usually zero.
- 5.2.4 *Lens tissue*, non-fluorescent, non-abrasive lens paper or tissue.