Diffuse brightness of pulp ($d/0^\circ$)

1. Scope

1.1 This method is to be used to evaluate the diffuse blue reflectance factor (diffuse brightness) of pulp by measuring handsheets prepared according to TAPPI T 218 “Forming Handsheets for Reflectance Tests of Pulp.” The measurement of handsheets is the most commonly accepted procedure for obtaining pulp brightness; however, machine-dried sheets can also be used.

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

1.2 This method utilizes an integrating sphere to provide diffuse illumination and perpendicular ($0^\circ$) observation geometry (1). With this geometry, specimen surface structure and azimuthal orientation have negligible effect on brightness.

1.3 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.

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

1.5 Although this method does not specifically exclude naturally fluorescent pulps or the use of optical brighteners, paper manufacturers may wish to limit their pulp suppliers in their use of optical brighteners. Such additives may reduce the potential for paper manufacturers to control brightness by the use of additional optical brighteners.

2. Summary

Diffuse reflectance is measured at 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.

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. 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 442 “Spectral Reflectance Factor, Transmittance, and Color of Paper and Pulp (Polychromatic Illumination),” T 524 “Color of White and Near-White Paper and Paperboard by $L, a, b\ 45^\circ 0^\circ$ Colorimetry,” and T 527 “Color of Paper and Paperboard in CIE $Y; x, y, or Y$, Dominant Wavelength and Excitation Purity”].
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 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.

NOTE 3: No known material is both perfectly reflecting and perfectly diffusing, but standards can be calibrated in terms of absolute reflectance (2). Standards with calibrations based on this reference can be obtained from ISO authorized laboratories.

4. Definitions

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

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.

5. Apparatus

5.1 **Reflectometer**, 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 Diffuse illumination of the specimen by means of an integrating sphere of 150 mm diameter. 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 in the sphere does not exceed 10% of the area 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 ± 0.5° at the center of the specimen aperture.

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 30 mm ± 1 mm.

5.1.1.6 The specimen aperture diameter shall not exceed 35 mm and the edge thickness shall not exceed 2 mm.

5.1.1.7 The specimen is viewed perpendicularly (0°). Only reflected rays within a solid cone, whose vertex is in 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 0.1% reflectance factor.

5.1.3 **Spectral characteristics**. The effective wavelength of the reflectometer, 457.0 nm ± 0.5 nm, is arrived at with a combination of lamps, integrating sphere, glass optics, filters or other spectrally selective device and photoelectric cells. The filters should be such that the relative spectral distribution function $F(\lambda)$ of the reflectometer is as indicated in Table 1: $F(\lambda)$ is the product of the following variables:

   a) the relative spectral distribution of the radiant emittance of the integrating sphere,
   b) the spectral transmittance of the glass optics,
   c) the spectral transmittance of the filters or other spectrally selective device, and
   d) the spectral response of the photoelectric cells, each being a function of the wavelength.
The relative spectral distribution function $F(\lambda)$ of a reflectometer equipment for measuring diffuse brightness of pulp.

<table>
<thead>
<tr>
<th>Wavelength, nm</th>
<th>$F(\lambda)$, arbitrary units</th>
<th>Wavelength, nm</th>
<th>$F(\lambda)$, arbitrary units</th>
</tr>
</thead>
<tbody>
<tr>
<td>380</td>
<td>0.0</td>
<td>450</td>
<td>82.5</td>
</tr>
<tr>
<td>390</td>
<td>0.0</td>
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<td>410</td>
<td>6.7</td>
<td>480</td>
<td>53.1</td>
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<td>18.2</td>
<td>490</td>
<td>20.3</td>
</tr>
<tr>
<td>430</td>
<td>34.5</td>
<td>500</td>
<td>5.6</td>
</tr>
<tr>
<td>440</td>
<td>57.6</td>
<td>510</td>
<td>0.3</td>
</tr>
</tbody>
</table>

5.2 The following ancillary items must be available:

5.2.1 *Instrument standards*, two or more opal glass or ceramic standards calibrated relative to a Level 2 (ISO) or Level 3 reference standard (see 7.3).

5.2.2 *Black cavity*, a black cylindrical cavity, with centering device, having a known reflectance of less than 0.5%.

5.2.3 *Lens tissue*, non-fluorescent, non-abrasive lens paper or tissue.

6. Reagents

*Cleaning solution*, distilled water and detergent free from fluorescing or abrasive ingredients.

7. Calibration and standardization

7.1 *ISO reference standard of level 1 (IR1)*, the perfect reflecting diffuser. Ideal spectrally uniform Lambertain diffuser with a reflectance equal to 100.0 at all wavelengths.

7.2 *ISO reference standard of level 2 (IR2)*, standard whose reflectance factor has been determined by a standardizing laboratory in relation to the IR1. These standards are used by authorized standardizing laboratories for the calibration of their reference instruments.

7.3 *ISO reference standard of level 3 (IR3)*, standard where the reflectance factor has been determined by an authorized standardizing laboratory in relation to any IR2. These standards are employed by instrument users for the calibration of their instruments.

7.4 *Instrument standards*, two opal glass or ceramic instrument standards are required. Wash standards with a solution of distilled water and detergent which is free from fluorescing or abrasive ingredients. Rub surface with a soft cloth or brush with synthetic fiber bristles. Rinse thoroughly with distilled water. Dry by blotting with filter paper. Place in a desiccator for additional drying until ready for use.

NOTE 4: An instrument standard in frequent use should be cleaned regularly, at least weekly, and it should be cleaned at any time that there is reason to suspect that the surface has become contaminated.

7.5 *Calibration of instrument standards*

7.5.1 Turn instrument on and allow it to come to operating equilibrium. Consult instruction manual for manufacturer's recommended warmup time and use of any lamp-house cooling technique that may be provided.

7.5.2 Clean two opal glass or ceramic instrument standards as described in 7.2.1, if they have not been cleaned recently.

7.5.3 Place the 457 nm filter set in position or select modified spectral equivalent.

7.5.4 Adjust instrument to read black cavity value with black cavity in specimen position.

7.5.5 Place the IR3 reference standard in the specimen position. Adjust the instrument to read the assigned value.

7.5.6 Place an opal glass or ceramic instrument standard in the specimen position and read the calibration value for this standard. Repeat the procedure to obtain the value for standard No. 2.
NOTE 5: The reflectance of opal-glass or ceramic standards is relatively stable; however, they must be calibrated at regular intervals on the specific instrument with which they will be used by making use of Level 3 reference standards and the procedures described in Section 7.

8. Use of instrument standards

Calibrate the instrument with standard No. 1 and then read standard No. 2. If the reading for standard No. 2 is not within 0.1% of its assigned value, clean it and reread. Use this reading as the new value for standard No. 2, and use this standard for the regular calibration of the instrument. Use standard No. 1 only to verify the calibration of standard No. 2.

NOTE 6: The relation between the calibrated values of the two instrument standards should remain constant. If a difference greater than 0.1% is observed, it is reasonable to assume that the calibration of standard No. 1 is more reliable because it has been used least. However, if the difference is greater than 0.2%, even after careful cleaning of both new standards, it would be advisable to procure a new Level 3 reference standard and to determine by this means whether the reflectance of one of the instrument standards has actually changed.

9. Test specimens

Prepare handsheets according to T 218. Remove the filter paper cover from the dried handsheets. Cut the handsheets into tabs large enough to cover the measurement aperture of the instrument. Use a pad of tabs of sufficient number that doubling it will not change the brightness reading. Six tabs may be sufficient.

10. Procedure

10.1 Place the 457 nm filter in position or select modified spectral equivalent and check black cavity reading (7.5.4). Place instrument standard No. 2 in position. Calibrate the instrument relative to this standard using the value obtained from the procedure described in Section 8.

NOTE 7: A single 150 mm diameter handsheet can be conveniently cut into six pre-shaped tabs using a paper cutter with a special template. The six tabs can be stored in the folded filter paper cover until ready to read the brightness.

10.2 Remove the top cover tab and place it on the bottom of the stack of tabs. Place the tabs, with the smooth side up, on a clean specimen holder.

10.3 Read the brightness of the first tab and record to the nearest 0.1%. Transfer the top tab to the bottom of the stack and make a brightness reading on the second tab. Repeat this procedure until five tabs have been read.

NOTE 8: Handle the specimens by the edges to avoid contamination. With many instruments, the brightness measurement must be made with reasonable speed because the reflectance may change as the moisture content of the surface of the specimen changes when heated by the instrument lamps. Color reversion also is possible with unstable material, so do not leave the stack of tabs against the specimen aperture while recording results.

NOTE 9: Since moisture content of the specimen has a slight effect on brightness, the best reproducibility is obtained by conditioning and making the tests in an atmosphere in accordance with TAPPI T 402 “Standard Conditioning and Testing Atmospheres for Paper, Board, Pulp Handsheets, and Related Products.”

11. Report

11.1 Report a precise identification of the sample.

11.2 Reference TAPPI Official Method T 525.

11.3 Report the brightness of the sample as the average of five tab readings to the nearest 0.1%.

11.4 Indicate whether data were obtained from measurement of a machine sheet or handsheet.

12. Precision

12.1 Data on the precision of measurement have been obtained from the published reports of the TAPPI-NBS Collaborative Reference Program (4) in which approximately 15 laboratories participated in the measurement of papers. The brightness values ranged between 75 and 81. The within-laboratory repeatability and the among-laboratory reproducibility were computed from the averages of the reported standard deviations in accordance with TAPPI T 1206 “Precision Statement for Test Methods.” It is assumed that the measurement precision for pulp would be comparable.
12.1.1 Repeatability: 0.2.
12.1.2 Reproducibility: 1.2.
12.2 The reader should be cautioned that these values are based on actual mill/laboratory brightness measurements with instruments or procedures that may not conform with this method. This information is given as a guide as to the potential variation in diffuse brightness evaluation that may exist across the industry.

13. Additional information

13.2 This revision differs from the 1972 version as follows:
13.2.1 The brightness reference has been changed from MgO to the perfect diffuser.
13.2.2 Detailed instrument calibration procedure has been eliminated. Refer to instrument manufacturer's instructions.
13.2.3 Inclusion of gloss trap has been added.
13.3 Related methods: ISO 2469, 2470, and 3688; CPPA E.1; SCAN P3; BSI 4432 Part 2470.

Literature cited


Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Technical Divisions Administrator.