



# Standard Test Method for Opacity of Paper (15° Diffuse Illuminant A, 89 % Reflectance Backing and Paper Backing)<sup>1</sup>

This standard is issued under the fixed designation D589; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the opacity of paper.

1.2 Two different types of “white” backing are specified, leading to two different opacity values, in accordance with Section 3.

1.3 This test method employs 15° diffuse geometry, Illuminant A/2° and 89 % reflectance backing or paper backing. For the measurement of opacity with  $d/0^\circ$  geometry, Illuminant C/2° and paper backing (see TAPPI T 519).

1.4 *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:<sup>2</sup>

D585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, and Related Product

D646 Test Method for Grammage of Paper and Paperboard (Mass Per Unit Area)

D685 Practice for Conditioning Paper and Paper Products for Testing

D1968 Terminology Relating to Paper and Paper Products

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

E308 Practice for Computing the Colors of Objects by Using the CIE System

### 2.2 TAPPI Standards:<sup>3</sup>

TAPPI Technical Information Sheet 0804-03—Interrelation

of reflectance,  $R_0$ ; reflectivity,  $R_\infty$ ; TAPPI opacity,  $C_{0.89}$  scattering,  $s$ ; and absorption,  $k$

TAPPI Technical Information Sheet 0804-06—Photometric linearity of optical properties instruments

T 519 Diffuse opacity of paper ( $d/0^\circ$  paper backing)

T 1206 Precision statement for test methods

## 3. Terminology

### 3.1 Definitions:

3.1.1 Definitions shall be in accordance with Terminology D1968 and the *Dictionary of Paper*.<sup>3</sup>

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *opacity (89 % reflectance backing)*,  $C_{0.89}$ —one hundred times the ratio of the diffuse reflectance,  $R_0$ , of a specimen backed by a black body of 0.5 % reflectance or less to the diffuse reflectance,  $R_{0.89}$ , of the same specimen backed with a white body having an absolute reflectance of 0.89; thus,  $C_{0.89} = 100 R_0/R_{0.89}$ . Accordingly, the contrast ratio is 100 % for perfectly opaque paper and is only a few percent for perfectly transparent sheets. (Sometimes called contrast ratio.)

## 4. Summary of Test Method

4.1 The reflectance of paper when combined with a white backing is higher than that of paper when combined with a black backing because in the former case, light transmitted through the imperfectly opaque sheet is largely reflected by the white backing, and a portion of the light thus reflected is transmitted through the paper a second time. Two types of “white” backing are used, leading to the two measurements of opacity defined in Section 3.

## 5. Significance and Use

5.1 Opacity is a fundamental optical property of paper as a whole, yet the measurement of opacity is empirical. The opacity of the sheet is influenced by the amount and kind of filler, degree of bleaching of the fibers, coating, and the like. The utility of bond, writing, and book papers may be enhanced by a high opacity.

5.2 The determination of opacity is of vital importance to both the manufacturer and the consumer. When white pigment is added to a sheet, it scatters more light, and thus increases opacity; however, it is also possible to increase opacity of a

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Technical Association of the Pulp and Paper Industry (TAPPI), 15 Technology Parkway South, Norcross, GA 30092, http://www.tappi.org.

sheet by adding dark pigment or dye which absorbs light. This being so, it is of value to the manufacturer, in meeting an opacity specification, to be able to predict whether a sheet which does not have desired opacity can be brought up to specification by raising or, alternatively, lowering the reflectivity within permissible limits. To the consumer, opacity measurements are used to evaluate some of the characteristics of appearance. The user is interested in the comparison of samples under identical conditions. When comparisons are made, one sample with another, very small differences can be identified visually. For this reason, small measured differences between similar samples represent actual differences in appearance.

## 6. Apparatus

6.1 *Opacity Meter*, equipped with an accurate linear or a corrected photometric system. The reflectance involved in the determination of contrast ratio should be for either normal illumination and diffuse viewing, or the equivalent converse, that is, diffuse illumination and normal viewing.

NOTE 1—The direction of illumination or, alternatively, the direction of viewing, should be  $15 \pm 2^\circ$  from the normal. The instrument may be designed to measure directly the ratio of reflectance of paper backed by black and white, or, alternatively, the instrument may be adjusted to indicate a cardinal value such as 100.0 with the white backing in place, and then the ratio of reflectances is obtained by replacing the white body with the black body. The photometric system must be sufficiently stable that the instrument will not fluctuate by more than approximately 0.1 % of the full-scale deflection while the contrast ratio is being measured.

6.2 The more important requirements of the apparatus are as follows:

6.2.1 *Standard Black Backing*, consisting of a cavity lined with black or velvet or other material which will cause the reflectance of the cavity to be 0.5 % or less.

6.2.2 *Standard White Backing*, having an effective absolute reflectance equal to 0.89 when illuminated under the conditions of actual testing with a sheet of paper in place (1).<sup>4</sup> This backing consists either of a permanent diffusing surface of the apparent reflectance in contact with the sample, or of an equivalent cavity such as that provided by a diffusing surface separated from the sample by a cover glass.

6.2.3 *Incandescent Light Source*, with the color temperature adjusted to yield an overall instrumental response equivalent to the Commission Internationale de l'Eclairage (CIE) function  $E_{ay}$  which has an effective wavelength of 572 nm. In a single-photocell instrument, stability requires that the voltage must not change by more than approximately 0.1 %.

6.2.4 *Photocell*, in combination with optical filters and lamp to produce an overall spectral response of the instrument equivalent to Commission Internationale de l'Eclairage (CIE) function  $E_{ay}$  (given in Table 1) which has an effective wavelength of 572 nm and closely approximates the response of the human eye.

6.2.5 *Integrating Cavity*, with inside surfaces coated with barium sulfate or halon. Total area of non-white surfaces

**TABLE 1 CIE  $E_a Y$  Weighting Functions, 10-nm Intervals (see Practice E308)**

nm	CIE $E_a Y$ Weighting Functions	nm	CIE $E_a Y$ Weighting Functions
400	0.000	600	7.547
410	0.002	610	6.360
420	0.008	620	5.061
430	0.027	630	3.716
440	0.061	640	2.559
450	0.117	650	1.639
460	0.209	660	0.971
470	0.362	670	0.533
480	0.618	680	0.289
490	1.039	690	0.147
500	1.802	700	0.075
510	3.091	710	0.039
520	4.756	720	0.020
530	6.320	730	0.010
540	7.599	740	0.005
550	8.571	750	0.003
560	9.219	760	0.001
570	9.456	770	0.001
580	9.224	780	0.000
590	8.543		

(including all openings) shall not exceed 6 % of the total white area. The specimen opening shall be round with a diameter of  $14.8 \pm 0.25$  mm ( $0.584 \pm 0.010$  in.). The illuminated area shall be circular with a diameter of  $9.53 \pm 0.38$  mm ( $0.375 \pm 0.015$  in.) and centered in the specimen opening. A light trap should be fitted inside the integrating cavity to limit stray light to no more than 0.5 %.

## 7. Sampling and Test Specimens

7.1 The material shall be sampled in accordance with Practice D585.

7.2 When sampling for other than acceptance purposes, Practice E122 may be used as an alternative.

7.3 At least five representative specimens shall be selected for each test unit. They shall be free of watermarks or blemishes and of sufficient size to fit the specimen holder, and completely cover the standard backings. The test areas shall not be touched with the fingers, and these areas shall be kept perfectly clean and free of folds and wrinkles.

## 8. Calibration

8.1 Check the calibration utilizing evaluated opal glass or paper standards and readjust as necessary in accordance with the manufacturer's instructions and Annex A1. After calibration, the instrument shall read the opal glass or paper standards within  $\pm 0.3$  of their assigned values.

## 9. Conditioning

9.1 Condition the test specimens in accordance with Practice D685.

## 10. Procedure

10.1 *Opacity (89 % Reflectance Backing)*:

10.1.1 Check the calibration using an opal glass or paper standard which is as close in value as possible to the specimen to be measured. If agreement is not within  $\pm 0.3$  recalibrate as instructed in Annex A1.

<sup>4</sup> The boldface numbers in parentheses refer to a list of references at the end of this standard.