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Opacity of paper (15/d geometry, illuminant A/2°, 89% reflectance backing and paper backing)

1. Scope and significance

1.1 Opacity is a fundamental optical property of paper as a whole, yet the measurement of opacity is determined by a ratio of reflectance measurements. The opacity of the sheet is influenced by thickness, the amount and kind of filler, degree of bleaching of the fibers, coating, and the like. The utility of bond, writing and book papers is enhanced by a high opacity.

1.2 The essential principle of this method for determining the opacity of paper is as follows: 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 is transmitted through the paper a second time thus increasing the total reflection. Two types of “white” backing are used, leading to two measures of opacity:

1.2.1 *Opacity (89% reflectance backing)*, sometimes called *contrast ratio*, $C_{0.89}$ is defined as 100 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 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.

1.2.2 *Opacity (paper backing)*, sometimes called *printing opacity*, is defined as 100 times the ratio of the light reflected by a paper specimen when the specimen is backed by a black body of 0.5% reflectance or less, R_0 , to that when the specimen is backed by a thick stack of the same kind of paper, R_∞ ; thus opacity (paper backing) = $100 (R_0/R_\infty)$.

1.3 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 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

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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.

1.4 This method employs 15/d geometry, illuminant A/2° and 89% reflectance backing or paper backing. For the measurement of opacity with d/0 geometry, illuminant C/2° and paper backing, see TAPPI T 519.

2. Apparatus

2.1 *Opacity meter*¹, equipped with an accurate linear or a corrected photometric system. The reflectance involved in the determination of contrast ratio should be for 15 degree direct illumination and diffuse viewing.

NOTE 1: The direction of illumination should be $15 \pm 1^\circ$ 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 reflectance 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 its full-scale deflection while the contrast ratio is being measured.

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

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

2.2.2 *Standard white backing*, having an effective absolute reflectance equal to 89% when illuminated under the conditions of actual testing with a sheet of paper (1). This backing consists either of a permanent diffusing surface of the appropriate reflectance in contact with the sample, or of a device which allows adjustment of the spacing between a diffuse white sample and a cover glass.

2.2.3 *Incandescent light source*, operated at a color temperature of $2854 \pm 200^\circ\text{K}$ and sufficiently stable to provide opacity readings within 0.1 opacity units. An infrared absorbing filter must be located between the lamp and specimen to eliminate sample heating.

2.2.4 *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 W_y for illuminant A, 1931 Observer as given in ASTM Standard E308-95, Table 6.1. This function has an effective wavelength of 572 nm and closely approximates the response of the human eye (2).

2.2.5 *Integrating cavity* with inside surfaces coated with barium sulfate or halon. Total area of non-white surfaces (including all openings) shall not exceed 6% of the total white area. The specimen opening shall be round with a diameter of 14.8 ± 0.25 mm (0.584 ± 0.010 in.). The illuminated area shall be circular with a diameter of 9.53 ± 0.38 mm (0.375 ± 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%.

3. Calibration

Check the calibration utilizing evaluated opal glass or paper standards¹ and readjust as necessary in accordance with the manufacturer's instructions and Appendix A. After calibration, the instrument must read the opal glass or paper standards within ± 0.3 of assigned values.

4. Sampling and test specimens

4.1 Obtain a sample in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product," free from watermarks or blemishes.

4.2 Cut at least five specimens of sufficient size to fit the specimen holder and completely cover the standard backings. Do not touch the test area with the fingers, and keep these areas perfectly clean and free from folds and wrinkles.

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.