WI 200804.02

T 480

DRAFT NO. 02 - SARG

DATE October 7, 2020

WORKING GROUP
CHAIRMAN N/A

SUBJECT
CATEGORY Optical Properties

RELATED
METHODS See "Additional Information"

Specular gloss of paper and paperboard at 75 degrees

(Five-year review of Official Method T 480 om-15)

(no changes from Draft 1; editorial corrections incorporated)

1. Scope

1.1 This method is for measuring the specular gloss of paper at 75° (15° from the plane of paper). Although its chief application is for coated papers (*1*), it is also used for a variety of uncoated papers.

1.2 This method is suitable for low- to high-gloss papers. For very high-gloss papers such as cast-coated, lacquered, highly varnished (*2-4*) or waxed papers (*5*), and high-gloss ink films (*6*), TAPPI T 653 "Specular Gloss of Paper and Paperboard at 20 Degrees" is preferred. T 480 has been shown to be suitable for gloss measurements of most ink films on paper or paperboard. Differences in the color and diffuse reflectance of these ink films have a negligible effect on measured gloss. For example, when white and black surfaces which are otherwise identical are tested, the white surface will measure less than one gloss unit higher than the black.

1.3 This method does not measure image-reflecting quality.

Approved by the Standard Specific Interest Group for this Test Method
TAPPI

2. Significance

This method is widely used as a partial measure of the surface quality and shiny appearance of coated paper.

3. Apparatus

3.1 *Gloss meter*[1], having the general arrangement and relative dimensions of the critical parts shown in Fig. 1. It consists of a source of light, a lens giving a converging beam of rays incident on the test specimen, a suction plate to hold the specimen flat, and a light detector to receive and measure certain rays reflected by the test specimen. These components are combined in a light-tight housing that is matte black inside and is structurally and optically stable during warming and at the operating temperature. Details of the geometric, spectral, and photometric characteristics of the instrument and of the specimen holder are given in Appendix A.

3.1.1 *Area of specimen illuminated*. The area illuminated is controlled by the dimensions of the aperture stop *A-A* specified in Fig. 1. If the outline of this spot is projected sharply onto the specimen, the illuminated area will be rectangular, $0.100d \pm 0.010d$ wide and $0.050d \pm 0.005d$ times 1/cos 75° long. When the value for d is 100 mm, the illuminated spot will have a width between 9.0 and 11.0 mm, and a length between 17.4 and 21.3 mm, resulting in an illuminated area between 156 and 234 mm^2.

3.2 *Gloss standards*[1]. The theoretical specular-gloss standard is an ideal, completely reflecting, plane mirror having an assigned value of 384.4 gloss units. A flat, clean, and highly polished surface of black glass having a refractive index of 1.540 for the sodium D line may be shown by the Fresnel equation (7) to measure 100 gloss units on this scale.

$$R_S = 0.5\left[\frac{sin^2(i-r)}{sin^2(i+r)} + \frac{tan^2(i-r)}{tan^2(i+r)}\right]$$

where:

i = angle of incidence (70 deg), (calculations made with angles converted to radians)

r = angle of refraction $\left(sin^{-1}\left(\frac{sin(i)}{n}\right)\right)$

and

n = refractive index

Alternatively, (R_S) may be written in the following way which is consistent with ISO 8254.

[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.

$R_S = 100 \cdot K$

$$K = \frac{\left(\dfrac{n^2 \cos i - (n^2 - \sin^2 i)^{1/2}}{n^2 \cos i + (n^2 - \sin^2 i)^{1/2}}\right)^2 + \left(\dfrac{(n^2 - \sin^2 i)^{1/2} - \cos i}{(n^2 - \sin^2 i)^{1/2} + \cos i}\right)^2}{\left(\dfrac{n_0^2 \cos i - (n_0^2 - \sin^2 i)^{1/2}}{n_0^2 \cos i + (n_0^2 - \sin^2 i)^{1/2}}\right)^2 + \left(\dfrac{(n_0^2 - \sin^2 i)^{1/2} - \cos i}{(n_0^2 - \sin^2 i)^{1/2} + \cos i}\right)^2}$$

where:

i = angle of incidence
n = refractive index of gloss being tested
n_0 = refractive index of gloss which reads 100.0 gloss units (1.540)

3.2.1 *High-gloss working standard*, a clean plaque of polished black glass for which the 75° specular reflectance has been computed from its refractive index as measured for the sodium D line.

3.2.2 *Intermediate-gloss standards*, having a reflected flux distribution comparable to that of the paper to be tested. Such standards may consist of ceramic tiles which are flat enough so that they do not rock when placed in the position of the specimen and are uniform in gloss over their central area. Each of these tiles is calibrated against the black glass standard on an instrument conforming with 3.1. For the purpose of this method, evaluated paper standards may be used for intermediate gloss verification.

NOTE 1: Store standards in a closed container when not in use. Keep standards clean and away from any dirt which might scratch or mar their surfaces. Never place standards face down on a surface which may be dirty or abrasive. Always hold standards at side edges to avoid transferring oil from one's skin to the standard surface. Clean standards in warm water and a mild detergent solution, brushing gently with a soft nylon brush. Do not use soap solutions to clean standards because they can leave a film. Rinse standards in hot running water (temperature near 150°F or 65°C) to remove detergent solution, followed by a final rinse in distilled water. Do not wipe intermediate standards. The polished black glass high-gloss standard may be dabbed gently with a lint-free paper towel or other lint-free absorbent material. Place rinsed standards in warm oven to dry.

NOTE 2: Black glass standards may not be stable and may change a few percent over a period of several years (*8*). The refractive index or gloss value should be verified from time to time against a stable standard. Major standardizing laboratories such as the National Institute of Science & Technology (NIST), USA, or the National Research Council, Canada, are able to verify the gloss values of such black glasses.

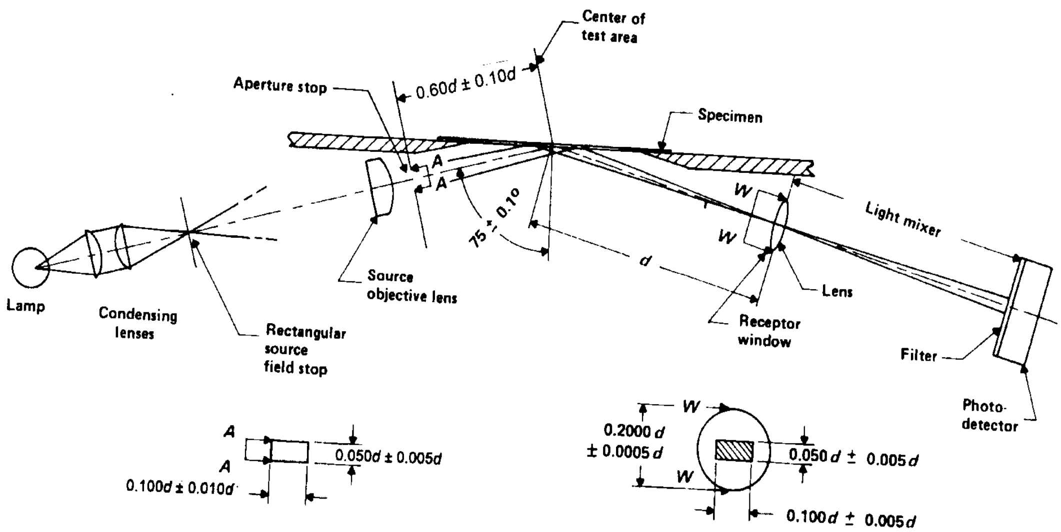

Fig. 1. Schematic drawing of glossmeter in which dimensions are given in terms of *d*, the distance between center of test area and receptor window. The cross-hatched rectangle in the *W-W* circle represents the image of the source field stop in the receptor window.

4. Sampling and test specimens

From each test unit obtained in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Containerboard, or Related Product," cut at least ten test specimens or select ten measurement areas free from folds or wrinkles or other blemishes and of sufficient size to cover completely the specimen opening of the instrument with an adequate overlap. Keep the specimens clean and do not touch the area to be tested. Condition and test the paper in an atmosphere of 50% + 5% - 10% RH and 23.0 ± 5.0°C (73.4 ± 9.0°F).

NOTE 3: The exposure of some papers to relative humidities of about 65% or above progressively and irreversibly decreases the gloss (*9*).

NOTE 4: Like other paper surface properties, gloss can be expected to vary from one side to the other. CD values are typically lower than MD values.

5. Procedure

5.1 Follow the instrument manufacturer's instructions for warming up and calibrating the gloss meter, assuring that the standards are properly cleaned.

5.2 Check the zero of the instrument with the specimen aperture covered with a black velvet-lined cavity, and then remeasure the black glass and intermediate-gloss standards. [Correct readings on the black glass and intermediate-gloss standards suggest that an instrument is in approximate, but not necessarily in exact, conformance with the above apparatus specification (*10*).] When readings differ by more than 1 gloss unit from assigned values, the instrument should be checked for conformance to the geometric, spectral, and photometric requirements.

5.3 Following the calibration check, measure at least 5 specimens or areas with the light path parallel to the machine direction. Measure the same number of areas with the light path parallel to the cross direction. Repeat for the other side of the sample, if desired.

NOTE 5: If the MD values vary by more than 1.0 unit when the sample is rotated 180°, make half of the MD measurements must be made in each orientation.

6. Report

Report the average of the MD and CD measurements as the TAPPI 75° Gloss value for the side tested. The minimum and maximum values and other data regarding the population of test values may also be reported.

NOTE 6: If your purposes require MD or CD values, make at least ten measurements in each direction of interest. Report these values as MD or CD, as appropriate.

7. Precision

The following estimates of repeatability and reproducibility are based on data from the CTS - TAPPI Interlaboratory Program for Paper & Paperboard. The test results were taken from Reports 166 through 170 from 1997. The following statistics are based on machine direction gloss values using three test results per sample. Each test result is based on 10 determinations with two replicate measures (upstream/downstream) per determination. Labs which were excluded from the interlaboratory report or conducted testing with a non-conforming instrument were excluded from these calculations. It should be noted that repeatability conditions were not followed in that test results from each lab were not taken at one time, but were separated by several months.

GLOSS UNITS

Material	*Grand mean*	*Repeatability r*	*Reproducibility R*	*Labs included*
.008 C1S Cover	84.21	1.35 1.6%	2.12 2.5%	36
70# Gloss Offset	72.89	4.59 6.3%	4.87 6.7%	39
65# Gloss Offset	48.62	1.99 4.1%	3.13 6.4%	25

Material	*Grand mean*	*Repeatability r*	*Reproducibility R*	*Labs included*
57# Gloss Offset	42.68	2.24 5.3%	3.02 7.1%	25
70# Dull Offset	28.63	2.12 7.4%	2.73 9.5%	30
Mean:		2.46 4.9%	3.17 6.4%	

Repeatability and reproducibility are estimates of the maximum difference (at 95%) which should be expected when comparing two test results from materials similar to those described above under similar test conditions. These estimates may not be valid for different materials or testing conditions.

These values are based on actual mill/laboratory measurements with procedures which may not conform to this method. This information is given as an estimate of the variation in 75° Gloss testing that exists across the industry.

8. Keywords

Paper, Paperboard, Gloss

9. Additional information

9.1 Effective date of issue: To be assigned.

9.2 Related methods: ANSI P3.23, T 653 “Specular Gloss of Paper and Paperboard at 20 Degrees.”

9.3 Changes from the 2009 version included editorial changes made to sections 1.1, 3.1, Note 1, Note 5, and Note 6.

Appendix A. Description of the instrument

A.1 *Optical system*. Referring to Fig. 1, beginning at the lamp, the dashed line indicates the path of the ray of light passing through the condenser lens and the geometric center of a rectangular aperture which becomes the effective source of light: through the source objective lens, through the geometric center of the rectangular aperture stop and to the specimen. This axial ray of light intersects the specimen plane at a point defined as the center of the test area. (This is not necessarily the geometric center of the illuminated area of the specimen.) With a plane front-surfaced mirror as the specimen, the axial ray is specularly reflected and passes through the center of the receptor window. The source objective lens makes an image of the source aperture at the receptor window. The distance *d*, from the center of the test area to the receptor window, is used as the basis from which to specify all other dimensions. The most critical dimensions are the angle of incidence, the position of the receptor window, and the diameter of the receptor window (*11,12*).

A.1.1 To achieve uniform weighting of the rays taking different paths through the receptor window, a light mixer (*10*) may be interposed between the receptor window and the photodetector. The positive lens is located adjacent to the receptor window and is arranged to collect all rays of light passing through the window and to form an image of the illuminated specimen surface on the photodetector sensitive surface, or on a diffusing screen immediately in front of this surface. No rays other than those reflected from the specimen surface are permitted to enter the receptor window.

A.1.2 *Angle of incidence*. The axial ray intersects the specimen plane at an angle of 75.0 ± 0.1°.

A.1.3 *Receptor window*. The diameter of the receptor window is expressed in terms of the distance *d*, from the center of the test area to the entrance plane of the receptor window and is 0.2000*d* ± 0.0005*d* and the thickness of its edge is not to exceed 0.005*d*. The axial ray, when reflected from a plane front-surface mirror in the specimen position, passes through the center of the receptor window within 0.0004*d* and is perpendicular to the plane of the receptor window.

A.1.4 *Position and size of light source aperture*. The position of the image of the light source aperture is in the plane of the receptor window with a tolerance, along the direction of the axial ray, of ± 0.04*d*. The size of the rectangular image is 0.100*d* ± 0.005*d* by 0.050*d* ± 0.005*d*, the short dimension of the rectangle lying in the plane of incidence (i.e., containing the incident and the specularly reflected axial ray).

A.1.5 *Position and size of the aperture stop*. The rectangular aperture stop is located 0.60*d* ± 0.10*d* from the center of the test area with its plane perpendicular to the axial ray. The size of the stop is 0.100*d* ± 0.010*d* by 0.050*d* ± 0.005*d*, the short dimension being in the plane of incidence. No other stops or diaphragms are permitted to intercept the incident rays of light.

A.1.6 *Spectral conditions*. The lamp, lenses, and photodetector shall be spectrally corrected to give a spectral response duplicating the CIE luminous efficiency function (Y_A), which has an effective wavelength of 572 nm.

A.1.7 *Light detector*. Any combination of photodetector and indicating device may be used, provided it indicates the true light flux to within ± 0.2 units over the entire 100-unit scale. The photometric linearity may be established by using the procedure described by Höfert and Loof (*13*).

A.1.8 *Specimen holder*. The suction plate for holding the specimens is firmly mounted and sufficiently flat so that the image in the receptor window of a thin, flexible plastic film of uniform thickness (for example, 0.003-in. thick, optical grade Mylar) held by this suction plate, will not be measurably different in position and size from that of the image formed by the black glass standard as described earlier. Suction plates may be made from a solid plate which contains two shallow grooves (or a single circular groove) on the side of the plate against which the specimen is held. The connection for supplying vacuum to the grooves may be made by drilling holes through the plate into each groove. Solid flat plates of brass or steel are suitable for making this type of suction plate.

Literature cited

1. The Institute of Paper Chemistry, Instrumentation Studies V, "Report on Gloss," *Paper Trade J.* **104** (1): 42 (Jan. 7, 1937); Instrumentation Studies VI. *Paper Trade J.* **104** (2): 42 (Jan. 14, 1937).
2. Hunter, R. S., "Method of Determining Gloss," *J. Research Natl. Bureau of Standards*, 1937; 18, 19 (R.P. 958).
3. Harrison, V.G.W., "The Definition and Measurement of Gloss," Cambridge, England, W. Heffer and Sons, Ltd., 145 pages.
4. Wink, W. A., Delevanti, C. H., Jr., and Van den Akker, J. A., Instrumentation Studies, LXXVII, "Goniophotometric Study of High-Gloss Papers," *Tappi* **36** (12): 163A (1953).
5. Hunter, R. S., and Lofland, C. A., "Gloss Test for Waxed Paper," *Tappi* **39** (12): 833 (1956).
6. Hunter, R. S., "Method of Evaluating the Gloss of Ink Films," *Tappi* **46** (7): 162A (1963).
7. Budde, W., "The Calibration of Gloss Reference Standards," *Metrologia* **16**: 89 (1980).
8. Budde, W., and Dodd, C. X., "Stability Problems in Gloss Measurements," *J. Coatings Technology* **52**: 44 (1980).
9. The Institute of Paper Chemistry, Instrumentation Studies XII, "Effect of Relative Humidity on Physical Properties with Respect to the Hysteresis Effect in Changes from One Humidity to Another," *Paper Trade J.* **104** (15): 45 (April 15, 1937).
10. Hunter, R. S., "Standardization of Test for Specular Gloss of Paper," *Tappi* **41** (8): 385 (1958).
11. Zabel, L. W., and Wink, W. A., "A Study of the Effects of Instrumental Variables on 75° Specular Gloss," *Tappi* **37** (10): 474 (1954).
12. Hammond, H. K. III, and Hsia, J. J., "Evaluation of Instrument Tolerances for 75° Gloss," *Tappi* **58** (11): 143 (1975).
13. Höfert, H., and Loof, H., "Calibration of the Photometric Scale of a Reflectance Photometer," *Zeitschrift für Instrumentenkunde* **72** (5): (1964) (in German). (English translation available from Carl Zeiss, 444 5th Ave., New York, N.Y. 10018).

Your comments and suggestions on this procedure are earnestly requested and should be sent to the TAPPI Standards Department. ■