Designation: D 1223 – 93 (Reapproved 1998)

An American National Standard

Standard Test Method for Specular Gloss of Paper and Paperboard at 75°[1]

1. Scope

1.1 This test method is for measuring the specular gloss of paper at 75° (15° from the plane of paper).

1.2 Although its chief application is to coated papers **(1)**,[2] this test method may also be used for uncoated papers.

1.3 This test method is not a measure of image-reflecting quality and should not be used for cast-coated, lacquered, highly varnished **(2, 3, 4)** or waxed papers **(5)**, and high-gloss ink films **(6)**. For these purposes, TAPPI T 653 "Specular Gloss of Paper and Paperboard at 20 Degrees" is preferred, although the present method has been shown to be suitable for gloss measurements of most other ink films on paper or paperboard. Here, differences in the color and the diffuse reflectances of these ink films have a negligible effect on measured gloss. For example, on comparing white and black surfaces which are otherwise identical, the white surface will measure less than one gloss unit higher than the black.

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:*

D 585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Products[3]

D 685 Practice of Conditioning Paper and Paper Products for Testing[3]

2.2 *TAPPI Standard:*

T 1200 Interlaboratory evaluation of test methods to determine TAPPI repeatability and reproducibility[4]

3. Significance and Use

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

4. Apparatus

4.1 *Gloss Meter*—(see 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 of the 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 Annex A1.

4.1.1 *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, $0.10d \pm 0.01d$ wide and $0.05 \pm 0.005d$ 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 length between 17.4 and 21.3 mm, resulting in an illuminated area between 156 and 234 mm^2. On the assumption that approximately 2000 mm^2 of paper or board should be evaluated to obtain a representative gloss value for the sample, 10 separate sheets or 10 different areas on one sheet should be measured and averaged.

NOTE 1—No minimum value for d is specified since none is required when a sufficient number of measurements is made so that the average provides a gloss value representative of 2000 mm^2 of sample.

4.2 *Gloss Standards*—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 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.

4.2.1 *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.

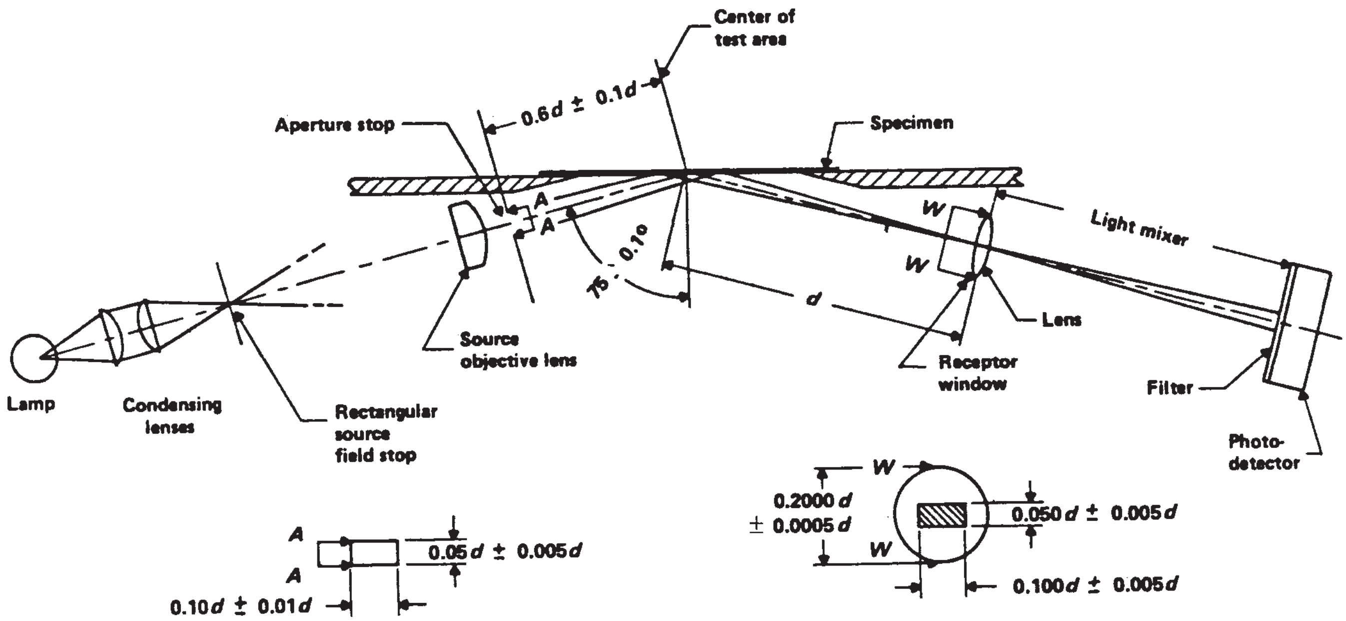
[1] This test method is under the jurisdiction of ASTM Committee D-6 on Paper and Paper Products and is the direct responsibility of Subcommittee D06.92 on Test Methods.

Current edition approved Oct. 15, 1993. Published December 1993. Originally published as D 1223 – 55T. Last previous edition D 1223 – 92.

[2] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[3] *Annual Book of ASTM Standards*, Vol 15.09.

[4] Available from the Technical Association of the Pulp and Paper Industry, Technology Park/Atlanta, P.O. Box 105113, Atlanta, GA 30348.



NOTE 1—Dimensions are given in terms of *d*, the distance between center of test area and receptor window.

NOTE 2—The cross-hatched rectangle in the *W-W* circle represents the image of the source field stop in the receptor window.

FIG. 1 Schematic Drawing of Glossmeter

4.2.2 *Intermediate-Gloss Standards*, having a reflected flux distribution comparable with 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 4.1.

NOTE 2—Store standards in a closed container when not in use. Keep them 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 getting oil from one's skin on 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 (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 a warm oven to dry.

NOTE 3—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 and Technology (NIST), USA, or the National Research Council, Canada, are able to verify the gloss values of such black glasses.

5. Sampling

5.1 Select a sample to represent the shipment in accordance with Practice D 585.

6. Test Specimens

6.1 From each test unit of the sample, cut at least ten test specimens free of folds or wrinkles or other blemishes and of sufficient size to cover completely the sample opening of the instrument with an adequate overlap. Keep the specimens clean and do not touch the area to be tested.

7. Conditioning

7.1 Condition and test the specimens in an atmosphere in accordance with Practice D 685.

NOTE 4—The exposure of paper to relative humidities of about 65 % or above progressively and irreversibly decreases the gloss **(9)**.

8. Procedure

8.1 Cover the specimen aperture with an opaque material and, with the instrument turned off, check the mechanical zero of the meter and adjust to zero if necessary. Then turn on the instrument and, after a 10-min warm-up period, insert the black glass standard and adjust the scale controls to give an instrument reading equal to the value of gloss for the standard.

8.2 Recheck the zero of the instrument with the specimen aperture covered with a black velvet-lined cavity to prevent external light from entering the receptor window. With the instrument turned on, the zero reading should agree with the mechanical zero setting. (Disagreement in the zero readings suggests that unwanted light rays are entering the receptor window.)

8.3 Reinsert the black glass standard and adjust the instrument as before, to give the correct value of gloss for the standard. Insert the intermediate standard and see that the instrument reads it correctly. (Correct readings on the black-glass and intermediate 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.

8.4 Following this calibration check, insert each specimen one at a time and read the gloss value. Rotate each specimen 180° and read the gloss value at the same point a second time.

Average the first and second readings for each specimen. In the absence of other information associated with the sample, perform the testing sequence in both the machine and cross directions for both the wire and felt sides of the sample. Insert the standards at frequent intervals to ensure that the instrument remains in adjustment throughout the period that the gloss measurements are being made and again at the end of the test.

8.5 Calculate for the ten specimens the four averages for the machine and cross directions and the wire and felt sides of the sample unless otherwise instructed.

9. Report

9.1 Report the average, maximum, and minimum gloss readings to the nearest unit for the felt side and for the wire side of the sample.

10. Precision and Bias

10.1 *Precision*:

10.1.1 The values in Table 1 are based on an interlaboratory study conducted in accordance with TAPPI T 1200. Eight papers at various gloss levels (ranging from approximately 10 to 80 gloss units) were tested by eleven laboratories. Twenty-five sheets of each paper were measured.

TABLE 1 Interlaboratory Study of Eight Papers Tested by Eleven Laboratories

Grand Mean	Repeatability	Reproducibility
10.94	1.84	2.22
26.71	3.25	4.01
29.99	3.86	4.93
42.48	5.27	7.28
60.32	8.60	9.31
66.20	4.18	5.40
72.29	9.54	9.87
80.40	5.58	6.53

10.1.2 Six of the eight papers from the interlaboratory study were also used in the CTS-TAPPI Collaborative Reference Program, Reports 119 through 124. Ten test determinations were made per sample and a minimum of 36 laboratories participated. The results were comparable to those obtained in the interlaboratory study and are as in Table 2.

10.1.2.1 The user of these precision data is advised that it is based on actual mill testing or laboratory testing, or both. There is no knowledge of the exact degree to which personnel skills or equipment were optimized during its generation. The precision provides an estimate of typical variation in test results which may be encountered when the test method is routinely used by two or more parties.

10.1.3 In both the interlaboratory study and the Collaborative Reference analyses, it appears that the major contributing factor to the precision of the data is the material variability.

10.2 *Bias*—The procedure in this test method has no bias because the value of gloss at 75° is dependent upon the test conditions specified in terms of this test method.

11. Keywords

11.1 coated paper; gloss; paper; paperboard; specular gloss; uncoated paper

TABLE 2 CTS-TAPPI Collaborative Reference Program (Reports 119–124)

Grand Mean	Repeatability	Reproducibility
27.12	3.05	4.60
30.30	4.07	5.09
42.73	4.99	7.52
59.08	7.37	8.67
66.52	3.16	6.29
80.56	5.29	6.45

ANNEXES

(Mandatory Information)

A1. DESCRIPTION OF INSTRUMENT

A1.1 *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*, the distance 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)**.

A1.2 To achieve uniform weighting of the rays taking different paths through the receptor window, a light mixer **(10)** is 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.

A1.3 *Angle of Incidence*—The axial ray intersects the specimen plane at an angle of 75.0 ± 0.1°.

A1.4 *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.

A1.5 *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 (that is, containing the incident and the specularly reflected axial ray).

A1.6 *Uniformity of Light in Source Aperture*—The distribution of light in the source aperture is required to be uniform in accordance with the following: Let the direction of the axial ray be the *z* axis, the *x* axis perpendicular to the plane of incidence, the *y* axis perpendicular to the *z* axis and parallel to the plane of incidence. Let the coordinates of the sides of the rectangular source be $\pm x_0$ and $\pm y_0$. Then, the rectangle is $2x_0$ long and $2y_0$ high. The distribution of light flux in the source aperture in the *y* direction is required to be so arranged as to satisfy the following equation:

$$\bar{y}/y_0 = \frac{\int_{-y_0}^{+y_0} F(y)y\,dy}{y_0 \int_{-y_0}^{+y_0} F(y)\,dy} = 0 \pm 0.05 \quad \text{(A1.1)}$$

where *F* (*y*) is the light flux per unit area expressed as a function of *y*, and further, that,

$$\bar{y}^2/y_0^2 = \frac{\int_{-y_0}^{+y_0} F(y)y^2\,dy}{y_0^2 \int_{-y_0}^{+y_0} F(y)\,dy} = 0.33 \pm 0.04 \quad \text{(A1.2)}$$

It should be recognized that for a perfectly uniform distribution of light, $\bar{y} = 0$ and $\bar{y^2} = y_0^{2/3}$. The light distribution in the *x* direction is required to satisfy the following equation:

$$\bar{x^2}/x_0^2 = \frac{\int_{-x}^{+x} F(x)x^2\,dx}{x_0^2 \int_{-x}^{+x} F(x)\,dx} = 0.33 \pm 0.03 \quad \text{(A1.3)}$$

The data for these equations may be obtained as described in Annex A2, and their application is discussed in Annex A3.

A1.7 *Position and Size of the Aperture Stop*—The rectangular aperture stop is located 0.6*d* ± 0.1*d* from the center of the test area with its plane perpendicular to the axial ray. The size of the stop is 0.10*d* ± 0.01*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.

A1.8 *Uniformity of Light in the Aperture Stop*—These tolerances are required to be the same as for the source aperture. Based on the coordinate system described, they are:

$$\bar{y} = 0 \pm 0.05y_0 \quad \text{(A1.4)}$$

$$\bar{y^2} = 0.33y_0^2 \pm 0.04y_0^2 \quad \text{(A1.5)}$$

$$\bar{x^2} = 0.33x_0^2 \pm 0.03x_0^2 \quad \text{(A1.6)}$$

With the specimen aperture open, and through the use of an auxiliary lens, an image of the aperture stop can be formed outside the instrument. Scanning of this image with a photometer, as described in Annex A2, yields the required information for determining the uniformity of light distribution in the aperture stop.

A1.9 *Spectral Conditions*—The incandescent source operates at a color temperature of 2850 ± 100 *K*. The photoreceptor is spectrally corrected by means of a filter so as to give the combination a spectral response duplicating the CIE luminous efficiency function, (Y_A) which has an effective wavelength of 572 nm.

A1.10 *Light Detector*—Any combination of photodetector and indicating device may be used, provided it gives a numerical indication of the light flux passing through the receptor window accurate over the entire scale to within ±0.2 % of full scale: that is, ±0.2 scale division for a scale comprised of 100 divisions. The photometric linearity may be established by using the procedure described by Höfert and Loof **(13)**.

A1.11 *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 measureably 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.

A2. MEASURING THE LIGHT UNIFORMITY OF THE SOURCE APERTURE

A2.1 With the specimen aperture open, the image of the source aperture will be formed outside the instrument and can be observed on a viewing screen such as a piece of white paper or ground glass. The image of the lamp filament should be centered in the image of the source aperture and should fill this aperture. By scanning this image of the source with a photometer of adequate sensitivity and one which has an aperture as discussed below, the required data can be obtained for determining the uniformity of light distribution in accordance with Eq A1.1, Eq A1.2, and Eq A1.3.

A2.2 The photometer scanning aperture may be circular or in the form of a long, narrow slit; its size, however, as discussed below, should be appropriately related to the size of the image of the source aperture and to the spacing of the lamp filament windings. The use of too small a scanning aperture introduces an undesirably high variation in the photometer readings, inasmuch as the photometer in this case will respond to the local changes in light intensity caused by the windings of the lamp filament. The use of too large an aperture, on the other hand, leads to an averaging of the intensity rather than to the measurement of its distribution. For example, in scanning an image showing eight filament windings, the scanning aperture should be of a size (that is, diameter or width of slit) equal to about ⅛ to ⅙ of the dimension of the rectangular source aperture image being scanned. For scanning the image, photometer readings should be obtained for at least six equally spaced positions for both the short and the long dimensions of the image. The integrations indicated in Eq A1.1, Eq A1.2, and Eq A1.3 should be performed on intensity data read from a smoothed curve of the plot of the photometric data. The procedure for obtaining a numerical approximation for the integrals in Eq A1.1, Eq A1.2, and Eq A1.3 is given in Annex A3.

A3. LIGHT UNIFORMITY IN THE SOURCE APERTURE AND IN THE APERTURE STOP

A3.1 In Fig. 1, the light source is shown to be formed by the image of a lamp filament inside a rectangular aperture. This arrangement is not mandatory, but it is probably the easiest way to make a light source with a precisely defined boundary. When this method is used, the light source will have point-to-point variations in intensity because of the filament shape. Such a source is certainly not uniform, although it will be photometrically equivalent if the flux distribution satisfies closely Eq A1.1, Eq A1.2, and Eq A1.3 given under geometric specifications. It is, of course, possible to defocus the lamp filament to improve the flux uniformity. Doing so, however, involves a possible risk of making the light flux nonuniform over the aperture stop. If the image of the filament is focused at or near the source aperture, however, the requirement for light uniformity at the aperture stop will likely be satisfied without further effort.

A3.2 The requirements in Eq A1.1, Eq A1.2, and Eq A1.3 can be better understood if a few typical flux distributions are considered. First, consider Eq A1.1 for the centroid of flux distribution with respect to the variable *y*. Suppose the flux per unit area is 1 unit at $y = 0$ and varies *linearly* from about ⅚ unit at $y = -y_0$ to 7⁄6 unit at $y = +y_0$. This distribution will meet the requirements of Eq A1.1 with a little margin and will be in perfect agreement with the requirements of Eq A1.2. Second, consider Eq A1.2 and Eq A1.3 for the average values of y^2 and x^2. These quantities are analogous to the square of the radius of gyration of a rotating body, and the flux distribution is analogous to the mass distribution. For this problem, consider a flux distribution that has its maximum at the center (x or $y = 0$) and tapers off *linearly* to a smaller value at the two ends ($x = \pm x_0$ and $y = \pm y_0$). If the flux density at the ends ($y = \pm y_0$) is ⅝ or greater, compared with its value at the center ($y = 0$), Eq A1.2 will be satisfied, and if its value at the ends ($x = \pm x_0$) is 7⁄10 or greater of its value at the center, Eq A1.3 will be satisfied.

A3.3 Symmetric distributions of this sort, of course, exactly satisfy the requirements of Eq A1.1. Sample calculations for the approximate solutions of Eq A1.1 and Eq A1.3 are shown subsequently. For this illustration, the flux distribution for the *y*dimension of the image for either the source aperture or the aperture stop is shown in Fig. A3.1 and that for the *x*dimension in Fig. A3.2.

A3.4 Using data obtained from Fig. A3.1, Table A3.1 shows the steps in the calculation of the summations involved in the equation:

$$y/y_0 = [\Sigma\, F(y)(y/y^0)] / [\Sigma\, R(y)] \quad (A3.1)$$

A3.5 Dividing the sum of the values in Column 3 by the sum of the values in Column 2 yields $y/y_0 = 0.015$. For this illustration of light distribution, the value of 0.015 meets the specification which states that y/y_0 is to lie within the range 0.0 ± 0.05.

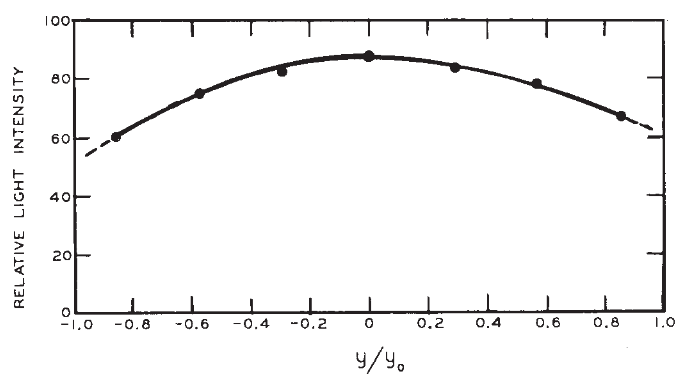


FIG. A3.1 Illustrative Data Showing Light Flux Distribution for Short Dimension of an Image of the Source Aperture or Aperture Stop, or Both. Positions of Plotted Points on y/y_0 Axis Correspond to the Use of a Scanning Slit Having a Width Equal to $2y_0/7$, or One-seventh of the Dimension Being Scanned.

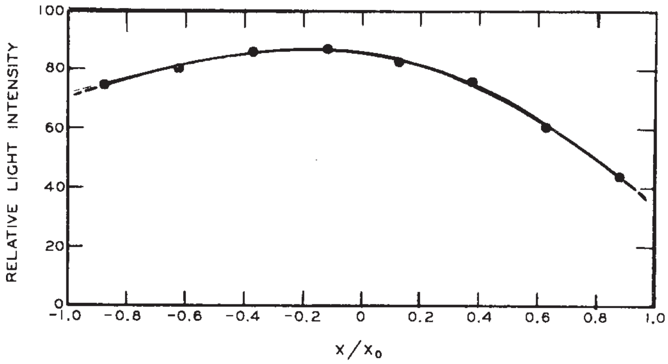


FIG. A3.2 Illustrative Data Showing the Light Flux Distribution for Long Dimension of an Image of the Source Aperture or Aperture Stop, or Both. Positions of the Plotted Points on x/x_0 Axis Correspond to the Use of a Scanning Slit Having a Width Equal to $2x_0/8$ or One-eighth of the Total Length.

A3.6 Using data obtained from Fig. A3.2, Table A3.2 shows the steps in the calculation of the summation involved in the equation:

$$x^2/x_0^2 = [\Sigma F(x)(x/x_0)^2] / [\Sigma F(x)] \quad (A3.2)$$

A3.7 Dividing the sum of the values in Column 4 by the sum of the values in Column 3 yields $x^2/x_0^2 = 0.292$. For this illustration of light distribution the value of 0.292 does not meet the specification which requires x^2/x_0^2 to lie within the range of 0.33 ± 0.03. Consequently, the uniformity of light distribution would have to be improved.

TABLE A3.1 Steps in the Calculation of the Summations of Eq A3.1

y/y_0	F(y)	F(y) (y/y_0)
0.1	86.0	8.6
−0.1	86.0	−8.6
0.3	84.0	25.2
−0.3	83.0	−24.9
0.5	79.0	39.5
−0.5	77.0	−38.5
0.7	73.0	51.1
−0.7	68.0	−47.6
0.9	65.0	58.5
−0.9	58.0	−52.2
	Σ = 759.0	Σ = 11.1

TABLE A3.2 Steps in the Calculation of the Summations in Eq A3.2

x/x_0	$(x/x_0)^2$	F(x)	F(x) $(x/x_0)^2$
0.1	0.01	84.0	0.84
−0.1	0.01	87.0	0.87
0.3	0.09	78.0	7.02
−0.3	0.09	86.0	7.74
0.5	0.25	69.0	17.25
−0.5	0.25	84.0	21.00
0.7	0.49	57.0	27.93
−0.7	0.49	80.0	39.20
0.9	0.81	43.0	34.83
−0.9	0.81	74.0	59.94
		Σ = 742.0	Σ = 216.62

REFERENCES

(**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).