WI 060804.01

T 519

DRAFT NO. 2

DATE June 13, 2006

TAPPI

WORKING GROUP CHAIRMAN PC Robertson

SUBJECT CATEGORY Optical Properties

RELATED METHODS See "Additional Information"

CAUTION:
This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

Diffuse opacity of paper (*d*/0 paper backing)

(Revision of T 519 om-02)

1. Scope

1.1 This method provides a measure of diffuse opacity (paper backing) of white and near-white papers, previously known as "printing opacity."

1.2 The method may be employed for colored papers on condition that their reflectance (paper backing) is greater than 20% and their diffuse opacity (paper backing) is greater than 45% (*1*).

1.3 The method is not suitable for highly transparent papers such as glassine.

1.4 This method employs *d*/0 geometry, illuminant C, and paper backing whereas TAPPI T 425 "Opacity of Paper" employs 15/*d* geometry, illuminant A, both 89% reflectance backing and paper backing.

1.5 This method is similar to ISO 2471.

2. Summary

Diffuse opacity, expressed as a percentage, is given by the ratio of the diffuse luminous reflectance factor of a single sheet with black backing (Y_0) to that with a backing consisting of a pad of the same paper (Y_∞), multiplied by 100, i.e., ($100 \times Y_0 / Y_\infty$).

NOTE 1: Light absorption coefficients *K* and light scattering coefficients *S* may also be determined from these reflectances if either the grammage of a sheet or its thickness is known (*2*,*3*).

3. Significance

3.1 This method indicates the extent to which a single sheet of paper hides (obscures) printed matter on underlying sheets of similar paper.

3.2 This method should not be confused with the opacity, white backing (TAPPI T 425) method, which assesses different optical properties (see section 15.3).

4. Definitions

4.1 *Diffuse luminous reflectance factor.* The diffuse luminous reflectance factor is the ratio of the luminous flux from a body diffusely illuminated (and viewed by the CIE 1931 standard colorimetric observer) to the luminous flux from the perfect diffuse reflector, identically illuminated and viewed.

4.2 *Diffuse luminous reflectance factor, Y_0.* The diffuse luminous reflectance of a single sheet backed with a black cavity.

4.3 *Diffuse luminous reflectance factor, Y_∞.* The diffuse luminous reflectance factor of a pad thick enough such that doubling its thickness does not affect its reflectivity.

4.4 *Diffuse opacity (paper backing) of paper.* The diffuse opacity (paper backing) of paper is the ratio, expressed as a percentage, of the diffuse reflectance factor, Y_0 to the diffuse reflectance factor, Y_∞, of the same paper, both values being measured with a reflectance meter or spectrophotometer in accordance with this method.

5. Apparatus

5.1 *Reflectance meter or spectrophotometer* [1], an instrument having the same geometric, photometric, and spectral characteristics described in Appendix A.1.

5.2 *Matched filters or equivalent device for modifying the spectral characteristics of the optical system,* providing the measuring instrument with an overall response equivalent to the CIE tristimulus value, *Y*, for CIE (1931)

[1] Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list in the set of TAPPI Test Methods, or may be available from the TAPPI Quality and Standards Department.

standard illuminant C, 2º standard observer.

5.3 *UV-cutoff filters*, required for instruments with strongly UV-emitting light source(s) to be interpositioned between the light sources and the *d*/0 integrating sphere to avoid the occurence of UV-excited fluorescence in the $Y(\lambda)$ spectral region from papers treated with fluorescent agents.

5.4 *Standard black cavity,* consisting of a cylindrical hollow body lined with black velvet or similar material, having a luminous reflectance less than 0.5%.

5.5 *Reference Standard*, traceable to IR2 or IR3 as described in Appendix A.2.

5.6 *Two working standards,* one for control purposes and one for regular use, calibrated in advance for luminous reflectivity against a reference standard supplied by an approved laboratory, as described in Appendix A.2.

6. Sampling

Sample representative test specimens in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Product."

7. Preparation of test specimens

7.1 From each test unit, cut rectangular specimens about 75 × 150 mm, free of watermarks, creases, dirt, holes, or other imperfections.

7.2 Place specimens in a stack with top sides up. Form a pad (stack) of such thickness that doubling the number of sheets does not affect the reflectance factor of the pad. Condition all test specimens.

NOTE 2: If the top side can be distinguished from the wire side (TAPPI T 455 "Identification of Wire Side of Paper""), turn the top side uppermost. If this distinction cannot be made, as may be the case for papers manufactured on double wire machines or for papers coated on both sides, turn the same side of all sheets in the pad upwards to ensure that diffuse opacity values can be evaluated separately for each side of the paper.

7.3 Protect the pad with additional specimen sheets on the top and bottom.

7.4 Avoid contamination and exposure to light and heat of both specimens and pad (specimen stack).

NOTE 3: When daylight fluors, such as fluorescent yellow, green, etc. are present in paper, their effect on the diffuse luminous reflectance factor cannot be removed using UV-cut off filters. This may lead to significant measurement differences on diffuse opacity of paper between different instruments. Thus the existence of daylight fluors on measured paper and preferably their estimated quantity (i.e. kg/T) should be stated in the final report.

8. Procedure for calibration of working standards

8.1 The working standards are calibrated according to the following procedure:

8.1.1 Check the instrument and bring it to stable operating conditions.

8.1.2 Clean the working standards as described in Appendix A.2.

8.1.3 Set the instrument to read CIE *Y* reflectance (see A.1.2.1).

8.1.4 Place the black cavity against the measuring aperture and adjust the instrument to read zero, or the assigned value in accordance with instrument manufacturer's instructions.

8.1.5 Place the approved standards laboratory's reference standard (traceable to ISO reference standard of level 2 or 3) against the measuring aperture, with the marked (or numbered) edge facing the operator, and adjust the instrument to read the value(s) assigned to this standard.

8.1.6 With the reflectance meter standardized as in 8.1.5, measure and record the reflectance (diffuse luminous reflectivity) of at least two working standards.

9. Procedure for checking the instrument

9.1 Check that the instrument is set to measure CIE *Y*, 2º standard observer.

9.2 Adjust the zero setting in accordance with 8.1.4.

9.3 Place working standard (evaluated in 8.1.6) against the aperture, check calibration, and adjust as necessary.

10. Procedure for measurement of diffuse opacity

10.1 Determine Y_0 and Y_∞ as follows:

NOTE 4: Where instruments are equipped with continuous illumination source emitters, make all reflectance measurements quickly to minimize potential color reversion.

10.1.1 Place a single specimen sheet against the measuring aperture of the instrument, supported by the black cavity, with the top side of the sheet towards the aperture.

10.1.2 Determine the reflectance, Y_0.

10.1.3 While holding the specimen sheet in place, replace the black cavity with an opaque pad of specimen sheets as the backing.

10.1.4 Determine the reflectance, Y_∞.

10.1.5 Repeat the measurement on the opposite side, if required, and record data for five specimen sheets.

10.1.6 If the range of values for Y_0 is greater than 0.5%, measure ten specimens to obtain a value that is representative of the paper.

10.1.7 Repeat this measurement on the opposite side. Record data for five specimen sheets.

NOTE 5: To avoid errors due to formation differences, measurements of Y_0 and Y_∞ should be made on the same sheets and in the same positions.

11. Calculation

11.1 Average the Y_0 and Y_∞ measurements for the five specimens, taking each side separately, and calculate the average diffuse opacity (paper backing) to the nearest 0.1%, according to:

$$\text{Diffuse opacity (paper backing)}, \% = 100\ Y_0/Y_\infty$$

12. Report

12.1 Report the average high and low opacity to the nearest 0.1%, stating the method used.

12.2 If the measured opacity from each side differs by 0.5% or more, report the opacity for each side separately.

13. Precision

13.1 The following estimates of repeatability and reproducibility are based on data from the CTS-TAPPI Interlaboratory Program from 1997 through 2000. Samples on which this data is based were uncoated printing and xerographic grades and standard 30# newsprint. Participants were asked to follow TAPPI Official Test Method T 519 om-96 to conduct this testing. Testing is based on 10 determinations per test result and 1 test result per lab, per material.

Repeatability = 0.4%

Reproducibility = 0.6%

The following chart shows representative data on which the figures above are based.

		Opacity Measurements					
Material description	**Grand Mean**	**Stnd Dev Btwn Lab Results**	**Repeatability r and %r**		**Reproducibility R and %R**		**Labs Included**
30# Newsprint	96.27	0.25	0.28	0.3%	0.68	0.7%	37
70# Offset	94.34	0.11	0.17	0.2%	0.30	0.3%	34
60# Offset	92.61	0.20	0.37	0.4%	0.55	0.6%	41
20# Xerographic	89.65	0.20	0.49	0.5%	0.55	0.6%	36

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

13.3 The user of these precision data is advised that it is based on actual mill testing, 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 quoted provides an estimate of typical variation in test results which may be encountered when this method is routinely used by two or more parties.

14. Keywords

Opacity, Paper, Reflectance, Diffuse reflection.

15. Additional information

15.1 Effective date of issue: to be assigned.

15.2 To reduce the opacities of different kinds of paper to relate to a common grammage, application of the Kubelka-Munk theory (*4*) provides the following formula:

$$\text{Opacity} = [100\ (A - 1)] / (A - R_\infty^{\,2})$$

where

$$A = [R_\infty\ (1 - Y_0 Y_\infty) / (Y_0 - Y_\infty)]^{x/w}$$

Y_0 and Y_∞ remain as measured, w is the conditioned grammage of the specimen in accordance with TAPPI T 410 "Grammage of Paper and Paperboard (Weight per Unit Area)," and x is the common grammage to which the diffuse opacity (paper backing) is reduced.

15.3 The diffuse opacity (white backing) corresponding to the diffuse opacity (paper backing) may be calculated from the equations in TAPPI T 425 or from the larger charts contained in TAPPI T 1214 "Interrelation of Reflectance, R_0; Reflectivity, $R\infty$; TAPPI Opacity, $C_{0.89}$; Scattering, s; and Absorption, k." The diffuse luminous reflectance factors Y_0 and Y_∞ of this method relate to CIE standard illuminant C. The bluer light from illuminant C is scattered more than that from illuminant A. Therefore, the value of diffuse opacity (white backing), either measured directly or obtained by use of the graph, may be as much as 1.0 point higher than the value obtained for the same paper according to TAPPI T 425.

15.4 Related methods: TAPPI T 425; ASTM D 589-94; ISO 2471 (1977); PAPTAC E.2; DIN 53 146; AFNOR Q 03-040; SCAN P-8.

Appendix A.1 Instrument specifications

A.1.1 Instruments for the measurement of diffuse opacity are similar to those described in TAPPI T 525, except for their overall spectral characteristics.

A.1.2 *Spectral characteristics.*

A.1.2.1 The overall spectral response of the reflectance meter or spectrophotometer shall be matched to the CIE tristimulus function $Y(\lambda)$ and 2º standard observer (1931), for CIE standard illuminant C.

A.1.2.2 An infrared absorbing filter must be located between the light source and specimen to eliminate specimen heating.

A.1.3 *Geometric characteristics.*

A.1.3.1 The specimen and reference are illuminated diffusely via an integrating sphere, 150 ± 5mm in diameter, covered on the inside with a stable highly reflecting and diffusing coating.

A.1.3.2 The sum total of the areas of all apertures in the sphere (for the specimen, the reference, two lamps, and two emerging light beams and any specimen observation aperture window) does not exceed 13% of the area of the sphere.

A.1.3.3 A gloss trap in the shape of a black annulus of internal diameter equal to that of the receptor aperture and of external diameter subtending a half angle of 15.0 ± 0.5º at the center of the sample aperture surrounds the aperture of the emerging specimen beam. No rays may be allowed to strike the specimen directly without first being reflected from the white inner lining of the sphere.

A.1.3.4 The specimen aperture is circular with a diameter of 34.0 ± 0.5 mm and a circumferential edge rim thickness not exceeding 1.5 mm. The effective test area viewed on the specimen surface is a circle of 30 ± 0.5 mm diameter.

A.1.3.5 The specimen is observed normally (0º). Only reflected rays within a solid cone, whose vertex is in the

specimen aperture and of half-angle not greater than 4º, shall fall onto the photodetector or photodetectors.

A.1.4 *Photometric characteristics.*

A.1.4.1 The photometric linearity error shall not exceed ± 0.2% full scale.

Appendix A.2 Calibration Standards

A.2.1 *ISO reference standard of level 1 (IR1),* the perfect reflecting diffuser. Ideal spectral uniform Lambertiaon diffuser with a reflectance equal to 100.0 at all wavelengths (*5*,*6*,*7*).

A.2.2 *ISO reference standard of level 2 (IR2),* standard where white 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.

A.2.3 *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. An IR3 standard provided with absolute reflectance values is used to establish calibration of the reflectance meter before measuring the working standard.

NOTE 6: A listing of ISO standardizing and authorized laboratories is available from the American National Standards Institute (ANSI) 430 Broadway, New York, New York 10018 USA.

A.2.4 *Working standards.* Two opal glass or ceramic working standards are required. Clean with a solution of distilled water and detergent which is free from fluorescing or abrasive ingredients. Rub surface with a soft cloth or soft bristle brush. Rinse thoroughly with distilled water. Blot dry with clean, lint-free tissue.

Literature cited

1. Budde, W., "Opacity Measurements on Colored Papers," *Pulp Paper Mag. Can.* **74** (8): TAPPI T 258 (1973).
2. Judd, D. B., and Wyszecki, G., "Color in Business, Science, and Industry," 3rd edn., John Wiley & Sons (1975).
3. Scallan, A., "An Alternative Approach to the Kubelka-Munk Theory," *J. Pulp Paper Sci.* **11** (3): (May 1985).
4. Kubelka, P., "New Contributions to the Optics of Intensely Light-Scattering Materials," *J. Opt. Soc. Am.* **38** (5): 448, 1067 (1948).
5. Budde, W., and Chapman, S. M., "The Calibration of Standards for Absolute Brightness Measurements with the Elrepho," *Pulp Paper Mag. Can.* **69** (7): TAPPI T 206 (1968).
6. Budde, W., and Dodd, C. X., "Absolute Reflectance in the *d*/0° Geometry," *Die Farbe* **19**: 94 (1970).
7. Budde, W., and Chapman, S. M., "The Measurement of Brightness and Opacity According to ISO Standards," transactions of CPPA Technical Section, Vols. 1 and 2, June 1975, pp. 61-64.

References

1. TAPPI T 1214 "Interrelation of Reflectance, R_0; Reflectivity, $R\infty$; TAPPI Opacity, $C_{0.89}$; Scattering, s; and Absorption, k."
2. Dearth, L. R., Shillcox, W. M. , Wink, W. A., and Van den Akker, J. A. "A Study of Instruments for the Measurement of Opacity of Paper v. Comparison of Printing Opacity Determined with Several Selected Instruments." *Tappi* **53** (3):436-41 (March 1970).
3. Wyszecki, G., and Stiles, W. S., "Color Science - Concepts and Methods, Quantitative Data and Formulae," Second Edition, John Wiley & Sons, 1982.

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

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T 519

DRAFT NO. 1

DATE February 17, 2006

TAPPI

WORKING GROUP CHAIRMAN to be assigned

SUBJECT CATEGORY Optical Properties

RELATED METHODS See "Additional Information"

CAUTION:
This Test Method may include safety precautions which are believed to be appropriate at the time of publication of the method. The intent of these is to alert the user of the method to safety issues related to such use. The user is responsible for determining that the safety precautions are complete and are appropriate to their use of the method, and for ensuring that suitable safety practices have not changed since publication of the method. This method may require the use, disposal, or both, of chemicals which may present serious health hazards to humans. Procedures for the handling of such substances are set forth on Material Safety Data Sheets which must be developed by all manufacturers and importers of potentially hazardous chemicals and maintained by all distributors of potentially hazardous chemicals. Prior to the use of this method, the user must determine whether any of the chemicals to be used or disposed of are potentially hazardous and, if so, must follow strictly the procedures specified by both the manufacturer, as well as local, state, and federal authorities for safe use and disposal of these chemicals.

Diffuse opacity of paper (*d*/0 paper backing)

(Five-year review of T 519 om-02)

1. Scope

1.1 This method provides a measure of diffuse opacity (paper backing) of white and near-white papers, previously known as "printing opacity."

1.2 The method may be employed for colored papers on condition that their reflectance (paper backing) is greater than 20% and their diffuse opacity (paper backing) is greater than 45% (*1*).

1.3 The method is not suitable for highly transparent papers such as glassine.

1.4 This method employs *d*/0 geometry, illuminant C, and paper backing whereas TAPPI T 425 "Opacity of Paper" employs 15/*d* geometry, illuminant A, both 89% reflectance backing and paper backing.

1.5 This method is similar to ISO 2471.

2. Summary

Diffuse opacity, expressed as a percentage, is given by the ratio of the diffuse luminous reflectance factor of a single sheet with black backing (Y_0) to that with a backing consisting of a pad of the same paper (Y_∞), multiplied by 100, i.e., ($100 \times Y_0 / Y_\infty$).

NOTE 1: Light absorption coefficients *K* and light scattering coefficients *S* may also be determined from these reflectances if either the grammage of a sheet or its thickness is known (*2*,*3*).

3. Significance

3.1 This method indicates the extent to which a single sheet of paper hides (obscures) printed matter on underlying sheets of similar paper.

3.2 This method should not be confused with the opacity, white backing (TAPPI T 425) method, which assesses different optical properties (see section 15.3).

4. Definitions

4.1 *Diffuse luminous reflectance factor.* The diffuse luminous reflectance factor is the ratio of the luminous flux from a body diffusely illuminated (and viewed by the CIE 1931 standard colorimetric observer) to the luminous flux from the perfect diffuse reflector, identically illuminated and viewed.

4.2 *Diffuse luminous reflectance factor, Y_0.* The diffuse luminous reflectance of a single sheet backed with a black cavity.

4.3 *Diffuse luminous reflectance factor, Y_∞.* The diffuse luminous reflectance factor of a pad thick enough such that doubling its thickness does not affect its reflectivity.

4.4 *Diffuse opacity (paper backing) of paper.* The diffuse opacity (paper backing) of paper is the ratio, expressed as a percentage, of the diffuse reflectance factor, Y_0 to the diffuse reflectance factor, Y_∞, of the same paper, both values being measured with a reflectance meter or spectrophotometer in accordance with this method.

5. Apparatus

5.1 *Reflectance meter or spectrophotometer* [1], an instrument having the same geometric, photometric, and spectral characteristics described in Appendix A.1.

5.2 *Matched filters or equivalent device for modifying the spectral characteristics of the optical system,*

[1] Names of suppliers of testing equipment and materials for this method may be found on the Test Equipment Suppliers list in the set of TAPPI Test Methods, or may be available from the TAPPI Quality and Standards Department.

providing the measuring instrument with an overall response equivalent to the CIE tristimulus value, *Y*, for CIE (1931) standard illuminant C, 2º standard observer.

5.3 *UV-cutoff filters*, required for instruments with strongly UV-emitting light source(s) to be interpositioned between the light sources and the *d*/0 integrating sphere to avoid the occurence of UV-excited fluorescence in the $Y(\lambda)$ spectral region from papers treated with fluorescent agents.

5.4 *Standard black cavity,* consisting of a cylindrical hollow body lined with black velvet or similar material, having a luminous reflectance less than 0.5%.

5.5 *Reference Standard*, traceable to IR2 or IR3 as described in Appendix A.2.

5.6 *Two working standards,* one for control purposes and one for regular use, calibrated in advance for luminous reflectivity against a reference standard supplied by an approved laboratory, as described in Appendix A.2.

6. Sampling

Sample representative test specimens in accordance with TAPPI T 400 "Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Product."

7. Preparation of test specimens

7.1 From each test unit, cut rectangular specimens about 75 × 150 mm, free of watermarks, creases, dirt, holes, or other imperfections.

7.2 Place specimens in a stack with top sides up. Form a pad (stack) of such thickness that doubling the number of sheets does not affect the reflectance factor of the pad. Condition all test specimens.

NOTE 2: If the top side can be distinguished from the wire side (TAPPI T 455 "Identification of Wire Side of Paper""), turn the top side uppermost. If this distinction cannot be made, as may be the case for papers manufactured on double wire machines or for papers coated on both sides, turn the same side of all sheets in the pad upwards to ensure that diffuse opacity values can be evaluated separately for each side of the paper.

7.3 Protect the pad with additional specimen sheets on the top and bottom.

7.4 Avoid contamination and exposure to light and heat of both specimens and pad (specimen stack).

NOTE 3: When daylight fluors, such as fluorescent yellow, green, etc. are present in paper, their effect on the diffuse luminous reflectance factor cannot be removed using UV-cut off filters. This may lead to significant measurement differences on diffuse opacity of paper between different instruments. Thus the existence of daylight fluors on measured paper and preferably their estimated quantity (i.e. kg/T) should be stated in the final report.

8. Procedure for calibration of working standards

8.1 The working standards are calibrated according to the following procedure:

8.1.1 Check the instrument and bring it to stable operating conditions.

8.1.2 Clean the working standards as described in Appendix A.2.

8.1.3 Set the instrument to read CIE *Y* reflectance (see A.1.2.1).

8.1.4 Place the black cavity against the measuring aperture and adjust the instrument to read zero, or the assigned value in accordance with instrument manufacturer's instructions.

8.1.5 Place the approved standards laboratory's reference standard (traceable to ISO reference standard of level 2 or 3) against the measuring aperture, with the marked (or numbered) edge facing the operator, and adjust the instrument to read the value(s) assigned to this standard.

8.1.6 With the reflectance meter standardized as in 8.1.5, measure and record the reflectance (diffuse luminous reflectivity) of at least two working standards.

9. Procedure for checking the instrument

9.1 Check that the instrument is set to measure CIE *Y*, 2º standard observer.

9.2 Adjust the zero setting in accordance with 8.1.4.

9.3 Place working standard (evaluated in 8.1.6) against the aperture, check calibration, and adjust as necessary.

10. Procedure for measurement of diffuse opacity

10.1 Determine Y_0 and Y_∞ as follows:

NOTE 4: Where instruments are equipped with continuous illumination source emitters, make all reflectance measurements quickly to minimize potential color reversion.

10.1.1 Place a single specimen sheet against the measuring aperture of the instrument, supported by the black cavity, with the top side of the sheet towards the aperture.

10.1.2 Determine the reflectance, Y_0.

10.1.3 While holding the specimen sheet in place, replace the black cavity with an opaque pad of specimen sheets as the backing.

10.1.4 Determine the reflectance, Y_∞.

10.1.5 Repeat the measurement on the opposite side, if required, and record data for five specimen sheets.

10.1.6 If the range of values for Y_0 is greater than 0.5%, measure ten specimens to obtain a value that is representative of the paper.

10.1.7 Repeat this measurement on the opposite side. Record data for five specimen sheets.

NOTE 5: To avoid errors due to formation differences, measurements of Y_0 and Y_∞ should be made on the same sheets and in the same positions.

11. Calculation

11.1 Average the Y_0 and Y_∞ measurements for the five specimens, taking each side separately, and calculate the average diffuse opacity (paper backing) to the nearest 0.1%, according to:

$$\text{Diffuse opacity (paper backing)}, \% = 100\ Y_0/Y_\infty$$

12. Report

12.1 Report the average high and low opacity to the nearest 0.1%, stating the method used.

12.2 If the measured opacity from each side differs by 0.5% or more, report the opacity for each side separately.

13. Precision

13.1 The following estimates of repeatability and reproducibility are based on data from the CTS-TAPPI Interlaboratory Program from 1997 through 2000. Samples on which this data is based were uncoated printing and xerographic grades and standard 30# newsprint. Participants were asked to follow TAPPI Official Test Method T 519 om-96 to conduct this testing. Testing is based on 10 determinations per test result and 1 test result per lab, per material.

Repeatability = 0.4%

Reproducibility = 0.6%

The following chart shows representative data on which the figures above are based.

		Opacity Measurements					
Material description	**Grand Mean**	**Stnd Dev Btwn Lab Results**	**Repeatability r and %r**		**Reproducibility R and %R**		**Labs Included**
30# Newsprint	96.27	0.25	0.28	0.3%	0.68	0.7%	37
70# Offset	94.34	0.11	0.17	0.2%	0.30	0.3%	34
60# Offset	92.61	0.20	0.37	0.4%	0.55	0.6%	41
20# Xerographic	89.65	0.20	0.49	0.5%	0.55	0.6%	36

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

13.3 The user of these precision data is advised that it is based on actual mill testing, 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 quoted provides an estimate of typical variation in test results which may be encountered when this method is routinely used by two or more parties.

14. Keywords

Opacity, Paper, Reflectance, Diffuse reflection.

15. Additional information

15.1 Effective date of issue: to be assigned.

15.2 To reduce the opacities of different kinds of paper to relate to a common grammage, application of the Kubelka-Munk theory (*4*) provides the following formula:

$$\text{Opacity} = [100\ (A - 1)] / (A - R_\infty^{\,2})$$

where

$$A = [R_\infty\ (1 - Y_0 Y_\infty) / (Y_0 - Y_\infty)]^{x/w}$$

Y_0 and Y_∞ remain as measured, w is the conditioned grammage of the specimen in accordance with TAPPI T 410 "Grammage of Paper and Paperboard (Weight per Unit Area)," and x is the common grammage to which the diffuse opacity (paper backing) is reduced.

15.3 The diffuse opacity (white backing) corresponding to the diffuse opacity (paper backing) may be calculated from the equations in TAPPI T 425 or from the larger charts contained in TAPPI T 1214 "Interrelation of Reflectance, R_0; Reflectivity, $R\infty$; TAPPI Opacity, $C_{0.89}$; Scattering, s; and Absorption, k." The diffuse luminous reflectance factors Y_0 and Y_∞ of this method relate to CIE standard illuminant C. The bluer light from illuminant C is scattered more than that from illuminant A. Therefore, the value of diffuse opacity (white backing), either measured directly or obtained by use of the graph, may be as much as 1.0 point higher than the value obtained for the same paper according to TAPPI T 425.

15.4 Related methods: TAPPI T 425; ASTM D 589-94; ISO 2471 (1977); PAPTAC Technical Section E.2; DIN 53 146; AFNOR Q 03-040; SCAN P-8.

Appendix A.1 Instrument specifications

A.1.1 Instruments for the measurement of diffuse opacity are similar to those described in TAPPI T 525, except for their overall spectral characteristics.

A.1.2 *Spectral characteristics.*

A.1.2.1 The overall spectral response of the reflectance meter or spectrophotometer shall be matched to the CIE tristimulus function $Y(\lambda)$ and 2º standard observer (1931), for CIE standard illuminant C.

A.1.2.2 An infrared absorbing filter must be located between the light source and specimen to eliminate specimen heating.

A.1.3 *Geometric characteristics.*

A.1.3.1 The specimen and reference are illuminated diffusely via an integrating sphere, 150 ± 5mm in diameter, covered on the inside with a stable highly reflecting and diffusing coating.

A.1.3.2 The sum total of the areas of all apertures in the sphere (for the specimen, the reference, two lamps, and two emerging light beams and any specimen observation aperture window) does not exceed 13% of the area of the sphere.

A.1.3.3 A gloss trap in the shape of a black annulus of internal diameter equal to that of the receptor aperture and of external diameter subtending a half angle of 15.0 ± 0.5º at the center of the sample aperture surrounds the aperture of the emerging specimen beam. No rays may be allowed to strike the specimen directly without first being reflected from the white inner lining of the sphere.

A.1.3.4 The specimen aperture is circular with a diameter of 34.0 ± 0.5 mm and a circumferential edge rim thickness not exceeding 1.5 mm. The effective test area viewed on the specimen surface is a circle of 30 ± 0.5 mm diameter.

A.1.3.5 The specimen is observed normally (0º). Only reflected rays within a solid cone, whose vertex is in the

specimen aperture and of half-angle not greater than 4º, shall fall onto the photodetector or photodetectors.

A.1.4 *Photometric characteristics.*

A.1.4.1 The photometric linearity error shall not exceed ± 0.2% full scale.

Appendix A.2 Calibration Standards

A.2.1 *ISO reference standard of level 1 (IR1),* the perfect reflecting diffuser. Ideal spectral uniform Lambertiaon diffuser with a reflectance equal to 100.0 at all wavelengths (*5*,*6*,*7*).

A.2.2 *ISO reference standard of level 2 (IR2),* standard where white 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.

A.2.3 *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. An IR3 standard provided with absolute reflectance values is used to establish calibration of the reflectance meter before measuring the working standard.

NOTE 6: A listing of ISO standardizing and authorized laboratories is available from the American National Standards Institute (ANSI) 430 Broadway, New York, New York 10018 USA.

A.2.4 *Working standards.* Two opal glass or ceramic working standards are required. Clean with a solution of distilled water and detergent which is free from fluorescing or abrasive ingredients. Rub surface with a soft cloth or soft bristle brush. Rinse thoroughly with distilled water. Blot dry with clean, lint-free tissue.

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