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Standard Test Method for Yellowness Index of Plastics[1]

This standard is issued under the fixed designation D 1925; 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 (ε) indicates an editorial change since the last revision or reapproval.

ε1 NOTE—Section 1.3 was added editorially October 1988.

1. Scope

1.1 This test method is intended primarily for determining the degree of yellowness (or change of degree of yellowness) under day-light illumination of homogeneous, nonfluorescent, nearly colorless transparent or nearly white translucent or opaque plastics. It is applicable to transmittance of transparent and translucent plastics and to reflectance of opaque plastics (Note 1). It is based upon tristimulus values calculated from data obtained on the Hardy-G.E.-type spectrophotometer,[2] but other apparatus is satisfactory if equivalent results are obtained.

1.2 The values stated in SI units are to be regarded as the standard.

NOTE 1—This test method has not been demonstrated for the determination of transmitted yellowness of plastics having a luminous transmittance below 25 %, and it has not been demonstrated for the determination of reflected yellowness of translucent plastics.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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:*

D618 Methods of Conditioning Plastics and Electrical Insulating Materials for Testing[3]

E 259 Recommended Practice for Preparation of Reference White Reflectance Standards[4]

E 308 Method for Computing the Colors of Objects by Using the CIE System[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *yellowness*—deviation in chroma from whiteness or water-whiteness in the dominant wavelength range from 570 to 580 nm.

NOTE 2—A definition of a method of obtaining dominant wavelength may be found in the literature.[6]

3.1.2 *yellowness index (YI)*—the magnitude of yellowness relative to magnesium oxide for CIE Source C. Yellowness index is expressed as follows:

$$YI = [100(1.28X_{CIE} - 1.06Z_{CIE})]/Y_{CIE}$$

where:

X_{CIE}, Y_{CIE}, and Z_{CIE} = tristimulus values (Note 3) of the specimen relative to Source C.

NOTE 3—By this test method, positive (+) yellowness index describes the presence and magnitude of yellowness; a specimen with a negative (−) yellowness index will appear bluish.

3.1.3 *change in yellowness index* (ΔYI)—the difference between an initial value, YI_0, and YI determined after a prescribed treatment of the plastic.

$$\Delta YI = YI - YI_0$$

NOTE 4—By this calculation, positive (+) ΔYI indicates increased yellowness and negative (−) ΔYI indicates decreased yellowness or increased blueness.

4. Significance and Use

4.1 Yellowness index obtained by this test method correlates reasonably well with the magnitude of yellowness perceived under day-light illumination.

4.2 Yellowness index of transparent and translucent plastics is a function of thickness. Comparison should be made only between specimens of comparable thickness.

4.3 For control work, tristimulus colorimeters are useful so long as their inaccuracies and differences from this primary test method are known.

4.4 This test method achieves its greatest accuracy in the determination of differences in yellowness index of sample versus a control of similar material and colorant composition. Change of yellowness index determined by this test method has proved useful in evaluation of degradation of plastics under exposure to heat, light, or other environment.

5. Apparatus

5.1 *Spectrophotometer, Recording,*[2] conforming to the requirements of Practice E 308. Other apparatus is satisfac-

[1] This test method is under the jurisdiction of the ASTM Committee D-20 on Plastics and is the direct responsibility of Subcommittee D20.40 on Optical Properties.

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[2] This spectrophotometer is described in Recommended Practice E 308. It is available as the Diano/Hardy Recording Spectrophotometer manufactured by the Diano Corp., P.O. Box 346, 75 Forbes Blvd., Mansfield, MA 02048.

[3] *Annual Book of ASTM Standards*, Vol 08.01.

[4] *Annual Book of ASTM Standards*, Vol 06.01.

[5] *Annual Book of ASTM Standards*, Vol 14.02.

[6] Hardy, A. C., *Handbook of Colorimetry*, Technology Press, Cambridge, MA.

tory if equivalent results are obtained.[7]

6. Reference Standards

6.1 *Primary Standard*—The primary standard for reflectance measurement is a layer of freshly prepared magnesium oxide prepared in accordance with Recommended Practice E 259. The primary standard for transmittance measurement is air.

6.2 *Instrument Standard*—Because of the difficulty of preparing a primary reflectance standard, magnesium carbonate, barium sulfate, or calibrated pieces of white structural glass known as Vitrolite may be used as instrument standards.

7. Test Specimen

7.1 This test procedure does not cover specimen preparation techniques.

7.2 Opaque specimens shall have at least one plane surface; transparent specimens shall have two surfaces that are essentially plane and parallel. Specimens not having plane surfaces may be compared on a relative basis if of the same shape and if similarly positioned for measurement.

8. Conditioning

8.1 *Conditioning*—Condition the test specimens at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Methods D 618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be 1°C (1.8°F) and ±3 % relative humidity.

8.2 *Test Conditions*—Conduct tests in the Standard Laboratory Atmosphere of 23 ± 2°C (73.4 ± 3.6°F) and 50 ±5 % relative humidity, unless otherwise specified in the test methods. In cases of disagreements, the tolerances shall be 1°C (1.8°F) and ±2 % relative humidity.

9. Procedure

9.1 Calibrate and operate the spectrophotometer in accordance with Method E 308. Calibrate and operate other instruments in accordance with instructions supplied by the manufacturer.

9.2 Obtain spectral transmittance data relative to air. For measurement of transmittance of translucent specimens, place freshly prepared matched magnesium oxide standards at the specimen and reference ports at the rear of the sphere. The interior of the sphere should be freshly coated with magnesium oxide and in good conditions.

NOTE 5—Magnesium oxide standards may be considered matched if on interchanging them the percent reflectance is altered by no more than 1 % at any wavelength between 400 and 700 nm.

NOTE 6—The energy transmitted by plastic specimens varies widely in angular distribution about the normal to the surface, depending upon the ability of the specimens to diffuse the incident light. Thus the amount of energy that strikes the surface at the specimen port may vary from nearly 100 % of the energy transmitted to a percentage determined by the relative areas of specimen port and sphere wall. Furthermore, the diffuse energy has a spectral composition such that the portion striking the surface at the specimen port is yellower than that which is more widely diffused.

NOTE 7—Matched magnesium carbonate blocks or matched Vitrolite tiles are not recommended in the measurement of translucent samples. Matched barium sulfate blocks with freshly scraped surfaces have been demonstrated to give results comparable to magnesium oxide, within the accuracy of this test method.

9.3 Obtain spectral directional reflectance relative to magnesium oxide. Exclude the specular component in reflectance measurement. Back the test specimens with a white standard to obtain spectral directional reflectance.

10. Calculation

10.1 Calculate the tristimulus values for Source C by numerical integration (see Practice E 308) from recorded spectral data or by automatic integration[8] during spectrophotometer operation.

10.2 Calculate the magnitude and sign of the yellowness index from the following equation:

$$YI = [100(1.28X_{CIE} - 1.06Z_{CIE})]/Y_{CIE}$$

10.3 For direct calculation of the yellowness index from filter photometer readings obtained with a tristimulus colorimeter see the equations in X1.4 of the Appendix. These equations eliminate the need for calculating the tristimulus values.

10.4 If desired, calculate the magnitude and direction of change in yellowness index from the following equation:

$$\Delta YI = YI - YI_0$$

11. Report

11.1 The report shall include the following:

11.1.1 Complete identification of the material tested,

11.1.2 Specimen thickness,

11.1.3 Magnitude and direction (sign) of the yellowness index, and

11.1.4 Identification of the instrument used by the manufacturer's model and serial number.

12. Precision and Bias

12.1 The rank-difference coefficient of correlation with subjective ranking for a series of 34 transparent, 38 opaque, and 34 translucent test specimens was 97.7, 99.5, and 98.7 %, respectively.

NOTE 8—Because of the Tyndall effect in light transmitted by translucent plastics, visual estimation of yellowness should be made with the specimen illuminated from behind by uniform diffuse illumination, nondirectional with respect to a line normal to the surface. Line-of-sight of the observer should also be normal to the viewed surface. The viewed surface should have a very low level of illumination falling upon it.

12.2 Limited tests conducted with this procedure indicate reproducibility among laboratories to be within ±0.3 units, for measurement of yellowness index of transparent and

[7] Tristimulus colorimeters giving direct readouts of Yellowness Index are: XL-10A Colorimeter with Yellowness Index Option (transmission attachment required for transparent samples) manufactured by Gardner Laboratory, Inc., 5521 Landy Lane, Bethesda, MD 20014, and the Hunterlab D25P Sphere Haze, and Color Difference meter with Yellowness Index option, manufactured by Hunter Associates Laboratory, 9529 Lee Highway, Fairfax, VA 22030.

[8] Davidson, H. R., and Imm, L. W., "Continuous, Automatic Tristimulus Integrator for Use with the Recording Spectrometer," *Journal of the Optical Society of America*, JOSAA, Vol 39, 1949, pp. 942–944.

opaque plastics, and ±2.6 units for measurement of transmitted yellowness of translucent plastics, with 95 % confidence.

12.3 For translucent plastics, rank correlation of instrumental measurement among four laboratories was in every case better than 98.4 %.

APPENDIX

(Nonmandatory Information)

XI. DERIVATION OF EQUATIONS FOR CALCULATION OF YELLOWNESS INDEX FROM PHOTOELECTRIC TRISTIMULUS COLORIMETER MEASUREMENTS

X1.1 By the definition given in 4.2, yellowness index has been defined as:

$$YI = [100(1.28X_{CIE} - 1.06Z_{CIE})]/Y_{CIE}$$

where:

X_{CIE}, Y_{CIE}, and Z_{CIE} = tristimulus values (CIE Source C) obtained by integration from spectrophotometric data as described in 10.1.

X1.2 The equations giving calculated tristimulus values from the filter photometer readings are as follows:

$$X_{CIE} = 0.7832\, A_o f_x + 0.197\, Z_o f_z$$
$$X_{CIE} = 1.000\, Y_o f_y$$
$$Z_{CIE} = 1.18103\, Z_o f_z$$

where:

A_o, Y_o, and Z_o = instrumental filter (amber, green, and blue reflectance) values relative to an instrument reference standard, and

f_x, f_y, and f_z = ratios of the reflectances of the instrument reference standard to magnesium oxide for each filter.

X1.3 Substituting these expressions for X_{CIE}, Y_{CIE}, and Z_{CIE} in the equation for yellowness index (X1.1),

$$YI = \frac{100[1.28(0.7832A_o f_x + 0.197Z_o f_z)] - 1.06(1.18103Z_o f_z}{1.0000\, Y_o f_y}$$

$$= \frac{100(1.002A_o f_x + 0.2524Z_o f_z - 1.2524Z_o f_z)}{Y_o f_y}$$

$$= 100(1.002A_o f_x - 0.999Z_o f_z)/y_o f_y$$

X1.4 Thus, within the precision of the test method for *reflectance* measurements,

$$YI = 100(A_o f_x - Z_o f_z)/Y_o f_y$$

For *transmittance* measurements ($f_x = f_y = f_z = 1$), this equation reduces to:

$$YI = 100(A_o - Z_o)/Y_o$$

These equations permit calculation of the yellowness index from tristimulus filter colorimeter readings without the labor of calculating approximate tristimulus values.

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