Designation: D 2805 – 96a

Standard Test Method for Hiding Power of Paints by Reflectometry[1]

This standard is issued under the fixed designation D 2805; 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.

INTRODUCTION

Using equations derived from Kubelka-Munk turbid media theory **(1-4)**[2] (see Annex A1), the reflectance of a coating can be predicted for any film thickness from measurements made at only one. On this basis several rapid and accurate test methods **(5, 6)** have been developed for determining hiding power. In the past such test methods have been considered difficult due to complexities, apparent and actual, in the treatment of data. The present test method has been simplified in this respect, primarily by adapting it fully for computer calculations.

Although the use of broad-band reflectometry makes this test method theoretically valid only for nonchromatic (white or gray) colors, good agreement has been obtained with chromatic paints as well. This is undoubtedly because the experimental measurements are made fairly close to the hiding power end point so that the Kubelka-Munk extrapolation and thus any associated error is relatively small.

This test method is therefore recommended without restriction as to color.

1. Scope

1.1 This test method covers the determination, without reference to a material paint standard, of the hiding power of air dry coatings with *Y tristimulus values greater than 15 %. With appropriate modification, it can also be used to test baking finishes.*

1.2 *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 344 Test Method for Relative Hiding Power of Paints by the Visual Evaluation of Brushouts[3]

D 1475 Test Method for Density of Paint, Varnish, Lacquer, and Related Products[3]

D 3924 Specification for Standard Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials[3]

E 284 Terminology Relating to Appearance[3]

E 1247 Test Method for Identifying Fluorescence in Object-Color Specimens by Spectrophotometry[3]

E 1331 Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry[3]

E 1347 Test Method for Color and Color Difference Measurement by Tristimulus (Filter) Colorimetry[3]

E 1349 Test Method for Reflectance Factor and Color by Spectrophotometry Using Bi-Directional Geometry[3]

3. Terminology

3.1 *Definitions*—For definitions used in this test method, see Terminology E 284.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *contrast ratio*—the ratio of the reflectance of a film on a black substrate to that of an identical film on a white substrate.

3.2.1.1 C_W—the contrast ratio with a white substrate of reflectance *W*.

$$\text{Thus: } C_W = R_0/R_W$$

3.2.1.2 *C*—the contrast ratio with a white substrate for which *W* = 0.80.

$$\text{Thus: } C = R_0/R_{0.80}$$

3.2.2 *reflectance*—the daylight luminous diffuse reflectance factor (specular reflection excluded). Also referred to in this test method as the *Y*-tristimulus value. This value may be

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

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

expressed as a percent or a decimal fraction, the latter being preferred and usually required for mathematical calculations.

3.2.2.1 *reflectivity,* R_∞—the reflectance of film thick enough to have the same reflectance over both a black and a white substrate.

3.2.2.2 R_0—the reflectance of a film on a black surface with a reflectance of 1 % or less, which is effectively zero for the purpose of this test.

3.2.2.3 *W*—the reflectance of a white substrate.

3.2.2.4 R_W—the reflectance of a film applied on a white substrate of reflectance *W*.

3.2.2.5 $R_{0.80}$—the reflectance of a film applied on a substrate having a reflectance of 80 %, which is the standard white-substrate reflectance in paint technology.

3.2.3 *scattering coefficient, S*—the ability of a material to internally scatter and thereby reflect light; expressed in this test method in the same units as spreading rate.

3.2.4 *spreading rate, H*—film area per unit volume of coating, in this test method expressed in square metres per litre (m^2/L). It is also frequently expressed in square feet per gallon (ft^2/gal).

3.2.4.1 *spreading rate,* H_X—an experimentally determined value of *H*.

3.2.4.2 *spreading rate,* H_C—value of *H* at a specified contrast ratio *C*.

3.2.4.3 *hiding power,* $H_{0.98}$—the spreading rate at the contrast ratio $C = 0.98$.

NOTE 1—It should be emphasized that a contrast ratio of 0.98 does not represent visually complete hiding, nor does it indicate that the same contrast ratio holds at every wavelength.

4. Summary of Test Method

4.1 The reflectivity R_∞ of the coating is determined from reflectance measurements on black and white hiding power charts.

4.2 The scattering coefficient *S* of the coating is determined from R_∞, and the reflectance R_0 and spreading rate H_X of a film applied on black glass.

4.3 The hiding power, $H_{0.98}$ of the coating is calculated from the reflectivity R_∞ and the scattering coefficient *S*.

4.4 As an optional procedure the contrast ratio *C* at a specified spreading rate H_C is calculated from R_∞ and *S*.

5. Significance and Use

5.1 This is a precise instrumental method giving results having an absolute physical significance without reference to a comparison paint. It should be used when maximum precision and minimum subjectivity are required, as in testing specification coatings or evaluating the hiding efficiency of pigments.

5.2 Hiding power Test Method D 344 is visual instead of instrumental, and gives results that are relative to a material standard instead of absolute. It is less precise than Test Method D 2805 but more closely aligned with practical painting procedures.

6. Apparatus and Materials

6.1 *Substrates*:

6.1.1 *Black Glass Panels*, [4] minimum size 200 by 200 mm, and approximately 6-mm thick.

6.1.2 *Black and White Paper Charts*[5]—The surface shall be smooth and level, and impervious to paint liquids. The black area shall have a maximum reflectance of 1 % and the white area a minimum reflectance of 78 %. The white area shall be non-fluorescent, as observed visually under ultra-violet illumination, or determined in accordance with Test Method E 1247.

6.2 *Balance*, accurate to 0.1 mg.

6.3 *Glass Slides*—Round or square plates of thickness similar to that used for microscope specimen slides, with a minimum area of 40 cm^2.

6.4 *Reflectance-Measuring Instrument*[6]—One that allows only diffusely reflected, radiant flux to be incident upon the measuring element. It shall employ a photometric system, including source, filters, and receptor, that provides a response closely similar to the product of the spectral luminous efficiency function of the CIE standard observer and source *C*. It shall provide readings to at least the third decimal place and permit estimation to the fourth.

6.5 *Template,*[7] with a film area approximately 100 cm^2 determined to the nearest tenth. Record the exact value on Line *C* of the worksheet shown in Fig. 1.

6.6 *Doctor Blade Film Applicators*, width 150 mm, clearances 50, 75, 100, 125, 150, 175, and 200 µm.

NOTE 2—With doctor blades made in the United States, estimate 25 mm/in. and 25 µm/mil. Bird-type applicators are usually marked with their half clearance.

6.7 *Computer and Software*, for solving the relevant Kubelka-Munk equations.

7. Procedure

7.1 *General Instructions*:

7.1.1 *Film Application*—Make drawdowns manually with a smooth uniform motion, at the rate of about 6 cm/s. Hold paper charts flat by a vacuum plate or other suitable device while making drawdowns.

7.1.2 *Reflectance Measurements*—Measure the reflectance of each test area at a minimum of three locations, reading or estimating to four decimal places and calculating mean values to the same. Place charts over a white surface and black glass over a black surface while measurements are being made.

[4] The sole source of manufacturer of the black Carrara glass known to the committee at this time is The Leneta Co., 15 Whitney Rd., Mahwah, NJ 07430. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[5] The sole source of manufacturer of the charts known to the committee at this time is the Leneta Co., 15 Whitney Rd., Mahwah, NJ 07430. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[6] Conforming with Test Methods E 1331, E 1347, or E 1349. Other methods for measuring the CIE-*Y* tristimulus value (specular reflection excluded) are permissible.

[7] The sole source of supply of the template known to the committee at this time is Paul Gardner Co., 316 N. E. First St., Pompano Beach, FL 33061. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

A. Paint Density, *D:* ____________ g/mL

B. Nonvolatile Content, *N:* ____________ (decimal fraction)

C. Template Film Area, *A:* ____________ cm²

D. Drawdowns on Charts:

Chart	R_0	R_w	W	C_w	R_∞
1					
2					
3					
4					
Mean	—	—	—		

$C_w = R_0/R_w$ $\quad R_\infty = f(R_0, R_w, W)$ $\quad$ Eq A1.1 of Annex A1

E. Drawdowns on Glass:

Panel	R_0	M, g	H_x, m²/L	S, m²/L	$H_{0.98}$, m²/L
1					
2					
3					
4					
Mean	—	—	—		

$H_x = \frac{AND}{10\,M} = \frac{\quad}{M}$ $\quad S = f(R_0, R_\infty, H_x)$ $\quad$ Eq A1.2 of Annex A1

$H_{0.98} = f(S, C, R_\infty)$ where $C = 0.98$ $\quad$ Eq A1.3 of Annex A1

G. Report

(1) Hiding power $H_{0.98}$ ____________ m²/L ____________ ft²/gal

(2) Reflectivity, R_∞ ____________

(3) Scattering coefficient, S ____________ m²/L

(4) Applicator clearance ____________ µm ____________ mils

(5) Contrast ratio, C_w ____________

(6) Sample identification

Type of paint ____________ Color ____________

Formula No. ____________ Batch or sample No. ____________

(7) Reflectometer description

Manufacturer ____________ Model name ____________

Model No. ____________ Type ____________

Geometry ____________ Aperture ____________

H. Alternative Hiding Power Report:

Specified spreading rate, H ____________ m²/L ____________ ft²/gal

Contrast ratio, C ____________

FIG. 1 Work Sheet Form

7.1.3 *Record Keeping*—Record all data on a copy of the worksheet form specified in Fig. 1. Typical data entries are shown in Fig. 2.

7.1.4 *Weight Measurements*—Make all weighings to 0.1 mg on the analytical balance.

7.2 *Paint density, D*—Determine the density in g/mL to four decimal places in accordance with Test Method D 1475 and record on Line *A* of the worksheet (Fig. 1). If the density is first determined in pounds per gallon, divide by 8.3454 to obtain it in grams per millilitre.

7.3 *Nonvolatile Content, N*—Sandwich 0.3 mL of paint (dispensed with a 1-mL syringe) between two previously weighed slides, squeezing them together so that the paint spreads to a diameter of about 45 mm. Reweigh to obtain the weight of paint sample. Separate the slides, allow the films to dry, and weigh a third time to determine the dry weight. Then calculate the nonvolatile content of the paint as a decimal fraction to four places. Run in duplicate and report the mean value to three decimal places on Line *B* of the worksheet (Fig. 1).

7.4 *Applicator Selection*—Make trial drawdowns on black and white charts at clearances of 100, 150, and 200 µm. Allow them to dry overnight and measure their contrast ratios. Based on the results select the best applicator for a contrast ratio of 0.97 ± 0.01, which may be one of the trial applicators or one of intermediate clearance. If it seems necessary, make an additional trial drawdown to confirm the correct applicator.

7.5 *Drawdowns on Glass and Charts*— Using the applicator selected from 7.4, make four drawdowns each on black glass and on black and white charts in accordance with 7.1.1. Leave enough of the white area of each chart uncoated to permit measurement of the reflectance *W*.

A. Paint Density, *D*: 1.246 g/mL

B. Nonvolatile Content, *N*: 0.499 (decimal fraction)

C. Template Film Area, *A*: 100.2 cm^2

D. Drawdowns on Charts:

Chart	R_0	R_w	W	C_w	R_∞
1	0.8755	0.9118	0.8157	0.9602	0.9452
2	0.8723	0.9112	0.8158	0.9573	0.9473
3	0.8758	0.9117	0.8123	0.9606	0.9463
4	0.8768	0.9117	0.8123	0.9617	0.9449
Mean	—	—	—	0.9600	0.9459

$C_w = R_0/R_w$ $R_\infty = f(R_0, R_w, W)$ Eq A1.1 of Annex A1

E. Drawdowns on Glass:

Panel	R_0	M, g	H_x, m^2/L	S, m^2/L	$H_{0.98}$, m^2/L
1	0.8760	0.4803	12.97	98.04	9.180
2	0.8785	0.4980	12.51	97.09	9.092
3	0.8793	0.4921	12.66	99.11	9.281
4	0.8798	0.5082	12.26	96.50	9.036
Mean	—	—	—	96.72	9.147

$H_x = \frac{AND}{10\,M} = \frac{\quad}{M}$ $S = f(R_0, R_\infty, H_x)$ Eq A1.2 of Annex A1

$H_{0.98} = f(S, C, R_\infty)$ where $C = 0.98$ Eq A1.3 of Annex A1

G. Report

(1) Hiding power $H_{0.98}$ 9.15 m^2/L 373 ft^2/gal

(2) Reflectivity, R_∞ 0.946

(3) Scattering coefficient, *S* 96.7 m^2/L

(4) Applicator clearance 125 µm 5 mils

(5) Contrast ratio, C_w 0.96

(6) Sample identification

Type of paint Exterior Latex Gloss Color White

Formula No. SF1436 Batch or sample No. 875-1234

(7) Reflectometer description

Manufacturer Photovolt Model name ________

Model No. 670 Type Colorimeter

Geometry 45-deg 0-deg Aperture 20 mm

H. Alternative Hiding Power Report:

Specified spreading rate, *H* 15.46 m^2/L 630 ft^2/gal

Contrast ratio, *C* 0.949

FIG. 2 Typical Work Sheet

7.6 *Drying of the Films*—Immediately after application place each drawdown horizontally in a well-ventilated dust-free location, with all drawdowns in close proximity to one another to assure identical drying conditions, and allow to dry a minimum of 40 h before testing. Drying conditions for film applications and nonvolatile determinations shall be the same, and in accordance with Specification D 3924.

7.7 *Reflectance Measurements*—On the second or third day after application measure the reflectances on all of the drawdowns within as brief a time span as possible, alternating the measurements between charts and glass rather than doing first all one and then the other. Enter the values of R_0, R_W, and W for charts into Section *D* of the worksheet, and the values of R_0 for glass into Section *E*.

7.8 *Weight of Dry Film, M*—After all of the reflectances are measured, position the template on the glass panels, each in its turn, and scrape off the surplus paint with a razor blade, to leave film areas defined by the template. If the template area is not already specified, measure one of the resultant films carefully to determine its area in square centimeters to the nearest tenth. Record this value on Line *C* of the worksheet (Fig. 1) as the characteristic area of the template. Then scrape off each paint film carefully into a weighing dish, weigh to 0.1 mg, and record the weights *M* in Section *E* of the worksheet, entering each weight adjacent to the value of R_0 for the same glass panel.

8. Calculation

8.1 In general, make the calculations and record to four significant figures and final report values to three. Enter calculated results in the worksheet (Fig. 1). Typical entries are shown in Fig. 2.

8.2 *Contrast Ratio C_W and Reflectivity R_∞*—From the data entered in Section *D* of the worksheet calculate C_W and R_∞ for each of the four charts, thus:

$$C_W = R_0/R_W \quad (1)$$

$$R_\infty = f(R_0, R_W, W)$$

Enter the values, as they are calculated, in the appropriate columns of Section *D*, then calculate and likewise enter their means.

8.3 *Spreading Rate* H_X—From the data recorded in the worksheet on Lines *A*, *B*, and *C* and in Section *E*, calculate the spreading rate H_x for each of the four glass panels, thus:

$$H_X = \frac{A \times N \times D}{10M}$$

where:

H_X = spreading rate, m^2/L,
A = template area, cm^2,
N = nonvolatile content of the paint,
D = density of the paint, g/mL, and
M = dry film weight, g.

and enter the values in the appropriate column of Section *E*.

8.4 *Scattering Coefficient S and Hiding Power* $H_{0.98}$—Continuing on Section *E* of the worksheet (see Fig. 1), and using the mean value of R_∞ from Section *D*, calculate for each of the glass panels, first *S* and then $H_{0.98}$ in square millimetres per litre as follows:

$$S = f(R_0, R_\infty, H_X) \quad (2)$$

$$H_{0.98} = f(S, C, R_\infty) \text{ given } C = 0.98 \quad (3)$$

Enter the values as they are calculated in the appropriate columns of Section *E*, then calculate and likewise enter their means.

8.5 *Contrast Ratio C at a Specified Spreading Rate H*—If desired, calculate the contrast ratio at a specified spreading rate using the mean values of R_∞ and *S* from worktable Sections *D* and *E*, of the worksheet (Fig. 1), thus:

$$C = f(S, H, R_\infty) \quad (4)$$

9. Report

9.1 Enter the following information on the indicated line in Fig. 1, Section *G*:

9.1.1 *Hiding Power,* $H_{0.98}$—Enter the mean value of $H_{0.98}$ from Section *E*, rounded to the second decimal place, onto Line *G* (*1*). If desired, multiply this value by 40.746 to obtain the value in square feet per gallon to the nearest whole number and enter it on the same line.

9.1.2 *Reflectivity*, R_∞—Enter the mean value of R_∞ from Section *D*, rounded to three significant figures, onto Line *G* (*2*).

9.1.3 *Scattering Coefficient*, *S*—Enter the mean value of *S* from Section *E*, rounded to three significant figures, onto Line *G* (*3*).

9.1.4 *Applicator Clearance*—On Line *G* (*4*) enter the clearance of the applicator, expressed in µm and if desired also in mils.

9.1.5 *Contrast Ratio*, C_W— Enter the mean value of C_W from Section *D*, rounded to the third decimal place, onto Line *G* (*5*).

9.1.6 On Line *G* (*6*) enter the identification and brief description of the coating.

9.1.7 On Line *G* (*7*) enter the identification and description of the reflectometer employed.

9.2 *Alternative Hiding Power Report: Contrast Ratio at a Specified Spreading Rate*—Enter the specified spreading rate *H* and the value of *C* calculated from 8.5, into Section *H* of the worksheet. This report may be in addition to or instead of conventional hiding power $H_{0.98}$.

10. Precision

10.1 *Precision*—The precision values given for this test method are based on two series of interlaboratory tests. For gray and chromatic paints **(7)**, five operators in five laboratories tested four gloss enamels covering a broad range of colors. For white paints **(5)**, five operators in five laboratories tested three white finishes covering the range of gloss to flat. The between-laboratory coefficients of variation were found to be those shown in Table 1.

TABLE 1 Precision of Hiding Power, $H_{0.98}$

	Coefficient of Variation	Maximum Acceptable Differences for Two Results	
		Repeatability	Reproducibility
Gray, and chromatic gloss finishes, %	3.5	<10.4	10.4
White finishes:			
Gloss, %	1.2	<4.7	4.7
Semigloss and flat, %	5.0	<16.3	16.3

11. Keywords

11.1 contrast ratio; hiding power (of paints/coatings); scattering coefficient; spreading rate

ANNEX

(Mandatory Information)

A1. ANNEX KUBELKA-MUNK EQUATIONS USED IN THIS TEST METHOD

$$R_\infty = f(R_0, R_W, W) \quad (A1.1)$$

$$a = \frac{1}{2}\left(R_W + \frac{R_0 + W - R_W}{WR_0} \right) \quad (A1.2)$$

$$R_\infty = f(a) = a - (a^2 - 1)^{1/2} \quad (A1.3)$$

$$S = f(R_0, R_\infty, H_X) \quad (A1.4)$$

$$b = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} - R_\infty \right) \quad (A1.5)$$

$$\underline{S = \frac{H_X}{2b} \ln \left(\frac{1 - R_0 R_\infty}{1 - R_0/R_\infty} \right)} \quad (A1.6)$$

$$H_C = f(S, C, R_\infty) \quad (A1.7)$$

$$a = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} + R_\infty \right) \quad (A1.8)$$

$$b = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} - R_\infty \right) \quad (A1.9)$$

$$U = \left[\left(a + \frac{1 - C}{1.60\, C} \right)^2 - \frac{1}{C} \right]^{1/2} + \frac{1 - C}{1.60\, C} \quad (A1.10)$$

$$P = f(U, R_\infty) = \frac{1}{2b} \ln \left(\frac{U + b}{U - b} \right) \quad (A1.11)$$

$$\underline{H = S/P} \quad (A1.12)$$

$$C = f(S, H, R_\infty) \quad (A1.13)$$

$$P = S/H \quad (A1.14)$$

$$a = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} + R_\infty \right) \quad (A1.15)$$

$$b = f(R_\infty) = \frac{1}{2}\left(\frac{1}{R_\infty} - R_\infty \right) \quad (A1.16)$$

$$C = \frac{a + b \ \coth bP - 0.80}{(a + b \coth bP)\,[1 - 0.80(a - b \coth bP)]} \quad (A1.17)$$

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