Designation: D 6045 – 02

An American National Standard

Standard Test Method for Color of Petroleum Products by the Automatic Tristimulus Method[1]

This standard is issued under the fixed designation D 6045; 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.

1. Scope

1.1 This test method covers the automatic determination of color of a wide variety of petroleum products such as undyed motor and aviation gasoline, aviation turbine fuels, naphthas, kerosine, pharmaceutical white oils, diesel fuel oils, heating oils, and lubricating oils by the automatic tristimulus method. This test method correlates to Test Method D 156 and Test Method D 1500 as calculated by the instrumentation.

NOTE 1—With the appropriate sample handling, this test method would apply to petroleum waxes, but they were not used in the round robin, and the precision of this test method with regard to waxes is unknown.

1.2 This test method reports results in terms of Test Method D 156 or Test Method D 1500.

1.3 This test method has a one-to-one correlation for the entire range of Test Method D 1500 ASTM Color and for the range from 0 to +30 for Test Method D 156 Saybolt color.

1.4 This test method does not apply to solid samples, petroleum products containing dye, and petroleum products having extreme fluorescence.

1.5 This test method does not apply to cloudy samples. Such samples shall be filtered so they are clear before measuring.

1.6 *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 156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)[2]

D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)[2]

D 2500 Test Method for Cloud Point of Petroleum Products[2]

D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products[3]

E 284 Terminology of Appearance[4]

E 308 Practice for Computing the Colors of Objects by Using the CIE System[4]

2.2 *Institute of Petroleum Standard:*

IP 17 Determination of Colour—Lovibond Tintometer[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *ASTM color*—the name of an empirical scale of expressing of the color of a petroleum liquid darker than Saybolt color based on a scale of 0.5 (lightest) to 8.0 Dil (darkest) and determined by Test Method D 1500.

3.1.2 *CIE*—the abbreviation for the French title of the International Commission on Illumination, or Commission Internationale de l'Eclairage. **E 284**

3.1.3 *CIE Standard Illuminant C*—Colorimetric illuminant, representing daylight with a correlated color temperature of 6774 K, defined by the CIE in terms of a relative spectral power distribution. **E 284**

3.1.4 *CIE 1931 standard observer*—ideal colorimetric observer with color matching functions $x(\lambda)$, $y(\lambda)$, $z(\lambda)$ corresponding to a field of view subtending a 2° angle on the retina; commonly called the" 2° Standard Observer" **E 284**

3.1.5 *saybolt color*—the name of an empirical scale for expressing of the color of a clear petroleum liquid based on a scale of −16 (darkest) to +30 (lightest) and determined by Test Method D 156.

3.1.6 *Tristimulus Values*—The amounts of three specified stimuli required to match a color.

3.1.6.1 *Discussion*—In the CIE system, they are assigned the symbols X, Y, and Z. **E 284**

4. Summary of Test Method

4.1 The sample is poured into the glass sample container, and the container is placed into the light path of the automatic instrument. A transmittance measurement is performed in order to determine the CIE tristimulus values (under CIE Standard Illuminant C and the CIE 1931 Standard Observer) of the

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.05 on The Properties of Fuels, Petroleum Coke and Carbon Material.

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[2] *Annual Book of ASTM Standards*, Vol 05.01.

[3] *Annual Book of ASTM Standards*, Vol 05.02.

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

[5] Institute of Petroleum, London, "Methods for Analysis Testing."

sample in question. These are then converted instrumentally by the appropriate algorithm to Saybolt color or ASTM color values.

4.2 The color of the sample is reported in either Test Method D 156 or Test Method D 1500 values, as appropriate.

5. Significance and Use

5.1 Determination of the color of petroleum products is used mainly for manufacturing control purposes and is an important quality characteristic because color is readily observed by the user of the product. In some cases the color may serve as an indication of the degree of refinement of the material. When the color range of a particular product is known, a variation outside the established range may indicate possible contamination with another product. However, color is not always a reliable guide to product quality and should not be used indiscriminately in product specifications.

6. Apparatus

6.1 Either instrument described in 6.1.1 or 6.1.2 may be used in this test method.

6.1.1 *Spectrophotometer*—The spectrophotometer used in the measurement shall satisfy the following specifications:

6.1.1.1 *Wavelength Range*—380–780 nm.

6.1.1.2 *Effective Wavelength Width*—The effective wavelength width of the radiant flux from the slit of the spectrophotometer shall be 10 ± 2 nm or 5 ± 1 nm.

6.1.1.3 *Linearity*—±0.5 % of full scale. Photometric reproducibility—±0.2 %.

6.1.1.4 *Wavelength Accuracy*—±1 nm.

6.1.1.5 *Geometrical Conditions*—Normal illumination and collection. The illumination light flux shall not include a ray which has an angle of five or more degrees toward the central line. The angle of the center line inclination of the illumination flux shall be 0 ± 2° toward the normal line of the sample surface.

6.1.1.6 The spectrophotometer shall have the capability to compute tristimulus values (CIE XYZ) using CIE Standard Illuminant C and the CIE 1931 Standard Observer.

6.1.1.7 A spectrophotometer that gives results comparable to those of the instrument described in 6.1.1.1 through 6.1.1.6 shall be satisfactory.

6.1.2 *Tristimulus Filter Colorimeter*—Instrument designed for high precision color measurement of clear liquids. The instrument shall be capable of converting the light transmitted by a sample (under normal illumination/normal detection) into tristimulus values (CIE XYZ) using the CIE Standard Illuminant C and the CIE 1931 Standard Observer using Practice E 308. A correlation between measured tristimulus values and Test Method D 1500 and Test Method D 156 numbers shall be used to yield an equivalent instrumental ASTM color and/or Saybolt value. The instrument shall be capable of automatically computing ASTM color or Saybolt values, or both.[6,7]

6.1.3 *Sample Cell*—Sample cell shall be clean, clear, colorless, and unaffected by the petroleum product being measured. Cells with path lengths of 33 mm have been found suitable for measuring ASTM color, and cells with path lengths of 100 mm have been found suitable for measuring Saybolt values. The operator shall follow the instrument manufacturer's procedures and recommendations.

7. Reagents and Materials

7.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society[8] where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 *Diluent*—Kerosine (**Warning**—Combustible. Vapor Harmful.) having a color of +21 saybolt color or lighter by this test method or Test Method D 156, or 1.5 by method B of IP 17. This material is used for diluting dark samples to be measured for ASTM color.

8. Sampling

8.1 Samples shall be taken in accordance with Practice D 4057.

9. Preparation of Sample

9.1 *Liquid Petroleum Products such as Lubricating Oils*—If the sample is not clear, heat it 6°C (10°F) above its cloud point (see Test Method D 2500) and observe the color at that temperature. When the sample is darker than ASTM Color 8, mix 15 volumes of the sample into 85 volumes of the kerosene, and test the mixture.

10. Procedure

10.1 *Calibration*—Prepare the spectrophotometer or tristimulus filter colorimeter for operation following the manufacturer's instructions.

10.1.1 Periodic measurement of suitable Test Method D 1500 or Test Method D 156, or both, comparative samples would verify instrumental performance. Refer to the manufacturer's documentation for specific details. A method for creating suitable samples is included in Appendix X1.

10.1.2 Basic calibration procedures are given in Appendix X2.

10.2 *Measurement*—Place the cell filled with the sample in the instrument, and measure according to the manufacturer's instructions.

10.3 Record the ASTM color value or Saybolt number as appropriate.

11. Report

11.1 Report the following information:

[6] The Minolta CT320 tristimulus transmission colorimeter has been found to be a suitable instrument.

[7] Supporting data are available from ASTM International Headquarters, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959. Request RR: D02-1356.

[8] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

11.1.1 The color of the sample as either Saybolt color to the nearest whole number or ASTM color according to the following procedure: (*1*) for results with decimal numerical values of x.1 to x.4, precede the value with the capital letter "L" and change the decimal value to x.5 (for example, for 3.1–3.4, report L3.5 ASTM color); (*2*) for results with decimal numerical values of x.5, report as stated (for example, for 3.5, report 3.5 ASTM color); (*3*) for results with decimal numerical values x.6–x.9, precede the value with the capital letter "L" and round up to the next larger whole value (for example, for 3.6–3.9, report as L4 ASTM color); (*4*) for results with decimal numerical values of x.0, report as stated (for example, for 4.0 report as 4.0 ASTM color); (*5*) for results greater than 8.0, report D 8 ASTM color.

11.1.2 If the sample has been diluted with kerosine, report the color of the mixture followed by the abbreviation Dil.

11.1.3 When the sample has been filtered, add the words" (sample filtered)".

12. Precision and Bias

12.1 A correlation has been derived between the manual Test Method D 156 Saybolt color and the manual Test Method D 1500 ASTM color, and this automatic method in a cooperative program involving five laboratories and ten petroleum materials. Data were generated in 1993 and details and statistical analyses are on file at ASTM Headquarters.[7]

12.2 *Precision*—The precision of this test method as obtained by statistical examination of interlaboratory test results is as follows:

12.2.1 *Repeatability*—The difference between successive test results obtained by the same operator with the same apparatus under constant operating conditions on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following value only in one case in twenty):

12.2.1.1 r = 0.14 Saybolt color units (Test Method D 156).

12.2.1.2 r = 0.10 ASTM color units (Test Method D 1500).

12.2.2 *Reproducibility*—The difference between two single and independent test results obtained by different operators working in different laboratories on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following value only in one case in twenty:

12.2.2.1 R = 1.24 (correlation with Test Method D 156).

12.2.2.2 R = 0.48 (correlation with Test Method D 1500).

12.3 *Bias*:

12.3.1 There is no bias in the correlation between this test method and Test Method D 1500.

12.3.2 There is no bias in the correlation between this test method and Test Method D 156 in the range from 0 to +30. There is a bias for the range from 0 to −16.

13. Keywords

13.1 ASTM color; automatic colorimeter; color measurement; petroleum products color; Saybolt; tristimulus

APPENDIXES

(Nonmandatory Information)

X1. PREPARATION PROCEDURE OF THE COLOR STANDARD SAMPLES

INTRODUCTION

This appendix is an explanation about preparation of color standard samples referred to in RR: D02-1356. It is also an example of the preparation of possible standard samples that can be used for periodic checks (see 10.1.1).

X1.1 Scope

X1.1.1 This appendix describes the preparation procedure of the Saybolt color standard samples and ASTM color standard samples.

X1.2 Referenced Documents

X1.2.1 *IEC Standard:*

IEC 867 Insulating Liquids—Specifications for Unused Liquids Based on Synthetic Aromatic Hydrocarbons[9]

X1.2.2 *Japanese Industrial Standard*:

K 0510 High Purity Dodecane[10]

X1.3 Apparatus

X1.3.1 The apparatus shall conform to the specifications set forth in 6.1 through 6.1.3.

X1.3.1.1 *Cells*—The optical path lengths shall be 10 mm, 33 mm, and 100 mm.

X1.3.1.2 *Balance*—The balance shall have a readability of 0.1 mg or better.

X1.3.1.3 *Pipette*—The capacity shall be 2 mL.

X1.3.1.4 *Volumetric Flasks*—The capacity shall be 200 mL and 250 mL.

[9] Available from American National Standards Institute, 25 West 43rd St., 4th Floor, New York, NY 10036.

[10] Available from Japanese Standards Association, 41–24 Akasaka Minato-ku, Tokyo 107–8440 Japan.

X1.3.1.5 *Erlenmeyer Flasks with Standard Taper Joint*—The capacity shall be 100 mL.

X1.3.1.6 *Beaker*—The capacity shall be 50 mL.

X1.4 Reagents

X1.4.1 *Dyes*:

X1.4.1.1 3-Methyl-1-phenyl-4-(phenyl azo)-pyrazol-5-ol (hereinafter referred to as Yellow 5GS-EX). The CAS RN (Chemical Abstracts Service Registry Number) is 4314-14-1.

X1.4.1.2 1-(phenyl azo)-2-naphthalenol (Orange EX). CAS RN 842-07-9.

X1.4.1.3 1,4 bis(butylamino)-9,10-anthracenedione (Blue SB). CAS RN 17354-14-2.

X1.4.1.4 1-[[4-[(dimethylphenyl)azo]dimethylphenyl]azo]-2-naphthalenol (Red 5B-SP). CAS RN 1320-06-5.

X1.4.1.5 1,5 (or 1,8)-bis[(4 methyl phenyl)amino]-9,10-anthracenedione (Violet 3R). CAS RN 8005-40-1.

X1.4.1.6 1-hydroxy-4-[(4-methyl phenyl)amino]-9,10anthracenedione (Violet B-2R). CAS RN 81-48-1.

X1.4.1.7 1,4-bis[(4-butyl phenyl)amino]-5,8-dihydroxy-9, 10-anthracenedione (Green SG). CAS RN 28198-05-2.

X1.4.2 *Alkyldiphenylethane*—Capacitor alkyldiphenylethane described in specification IEC 867, which has a density of 0.9865–0.9877 g/cm^3 at 15°C.

X1.4.3 *Dodecane*—In accordance with JIS K0510 or those with composition as shown in X1.4.3.1, and with tristimulus values XYZ in X1.4.3.2.

X1.4.3.1 The spectral transmittance (value at 5-nm intervals) at 380–780 nm shall be measured by the spectrophotometer (wavelength width: 5 nm, cell: 100 mm). In accordance with Practice E 308, calculate the tristimulus values of X, Y, and Z using the values for CIE Standard Illuminant C and the 1931 Standard Observer.

X1.4.3.2 *Composition of Dodecane (unit: volume %)*:

Component	Amount
Undecane	0.2 or less
Dodecane	99.5 or more
Tridecane	0.2 or less

X1.4.3.3 *Tristimulus Values of Dodecane:*

Stimulus Value	Specification
X	90.00 or more
Y	92.00 or more
Z	105.00 or more

X1.5 Preparation Procedure for the Saybolt Color Standard Samples

X1.5.1 The Saybolt color standard samples are prepared through the following three steps: (*1*) preparation of the dye solution, (*2*) preparation of the Saybolt Color mixed dye solution, and (*3*) preparation of the Saybolt color standard sample.

X1.5.1.1 *Preparation and Verification of the Dye Solution*:

(a) Measure 0.2500 ± 0.0005 g of yellow 5GS-EX into a 50-mL beaker. Dissolve the dye with 20 mL of alkyldiphenylethane, pour the solution into a 250-mL volumetric flask, add alkyldiphenylethane to the marked line, and mix well. Hereinafter this is called Yellow 5GS-EX Dye Solution.

(b) Repeat the above procedure for Orange EX dye and Blue SB dye. Hereinafter these solutions are called Orange EX Dye Solution and Blue SB Dye Solution.

(c) Check the absorption of the dye solution as follows: Place 2 mL of the Yellow 5GS-EX Dye Solution into a 200-mL volumetric flask. Add dodecane to the marked line and then mix well. In a separate flask, repeat the procedure for Orange EX and Blue SB. Using a spectrophotometer (wavelength width: 5 nm, cell: 10 mm), with dodecane as thecontrol, measure the absorption of the three solutions prepared and compare them to the values in Table X1.1. If they do not meet the specifications, redo the procedures.

X1.5.1.2 *Preparation of the Saybolt Color Mixed Dye Solution*:

(*a*) Measure the three dye solutions prepared above according to the following specifications, and mix them in a 100-mL Erlenmeyer flask:

Dye Solution	Quantity (g)
Yellow 5GS-EX	30.000 ± 0.010
Orange X	10.000 ± 0.005
Blue SB	1.000 ± 0.001

Measure 5.000 ± 0.001 g of the solution prepared above and place it in a 100-mL Erlenmeyer flask. Add 45.000 ± 0.001 g of dodecane and mix well. Hereinafter this is called Saybolt color mixed dye solution.

X1.5.1.3 *Preparation and Verification of Saybolt Color Standard Samples*:

(a) Measure the quantity of the Saybolt color mixed dye solution as shown in Table X1.2, and place it in a 50-mL beaker. Add 20 mL dodecane and mix. Then place them in a 250-mL volumetric flask, add dodecane to the marked line, and mix well.

(b) For each of the seven solutions above, measure the transmittance between 380–780 nm with a spectrophotometer (wavelength width: 5 nm, cell: 100-mm path length).

(c) Calculate the stimulus value Y of the XYZ color system and chromaticity coordinates x, y, and z from the spectral transmittance (the value at 5 nm intervals) by using the values for CIE Standard Illuminant C and the 1931 Standard Observer according to Practice E 308. When the values of Y, x, y, and z meet the specifications in Table X1.3, the samples can be used as Saybolt color standard samples S + 30, S + 25, S + 19, S + 15, S + 12, S0 and S−15. The Saybolt color of each of these color standards is + 30, + 25, + 19, + 15, + 12, 0, and − 15, respectively. If the values of Y, x, y, and z do not meet the specifications in Table X1.3, repeat the above procedure.

X1.5.1.4 *Preparation Procedure for the ASTM Color Standard Samples*—ASTM Color Standard Samples are prepared

TABLE X1.1 Dye Solution Absorption Range

Dye Solution	Wavelength, (nm)	Absorption
Yellow 5GS-EX	395	0.881–0.935
Orange EX	465	0.519–0.541
Blue SB	600	0.412–0.438
	645	0.465–0.494
Red 5 B-SP	515	0.673–0.715
Violet 3R	545	0.337–0.358
Violet B-2R	585	0.332–0.353
	635	0.400–0.424
Green SG	680	0.467–0.498

TABLE X1.2 Saybolt Color Mixed Dye Solution

Saybolt Color Standard Samples	Required Amount of the Saybolt Color Mixed Dye Solution (g)
S+30	0.200 ± 0.001
S+25	0.472 ± 0.002
S+19	1.087 ± 0.002
S+15	1.724± 0.003
S+12	2.083 ± 0.004
S0	4.545 ± 0.005
S−15	8.772 ± 0.010

through the following three steps: (*1*) preparation of the dye solution, (*2*) preparation of the ASTM color mixed dye solution, and (*3*) preparation of the ASTM color standard sample.

(a) Preparation of the Dye Solution—Measure 0.2500 ± 0.0005 g of Yellow 5GS-EX dye and put it into a 50-mL beaker. Dissolve the dye with 20 mL of alkyldiphenylethane. Place the solution into a 250-mL volumetric flask, add alkyldiphenylethane to the marked line, and mix well. Hereinafter this is called Yellow 5GS-EX dye solution.

(b) Repeat the above procedure for Orange EX, Blue SB, Red 5B-SP, Violet SR, Violet B-2R, and Green SG in alkyldiphenylethane, respectively. Hereinafter they are called Orange EX dye solution, Blue SB dye solution, Red 5B-SP dye solution, Violet 3R dye solution, Violet B-2R dye solution, and Green SG dye solution.

(c) Check the absorption of the dye solution as follows: Place 2 mL of the Yellow 5GS-EX dye solution into a 200-mL volumetric flask. Add dodecane to the marked line and then mix well. In the same way, add dodecane to the six other dye solutions and mix well. By using a spectrophotometer (wavelength width: 5 nm cell: 10 mm), with dodecane as the control, measure the absorption of the seven solutions prepared to confirm that the absorption meets the specification in the Table X1.1. If the absorbency does not meet the specifications, redo the procedures above.

(d) Preparation of the ASTM Color Mixed Dye Solution—Of the seven dye solutions which were prepared, measure the amount as specified in Table X1.4, and mix them in a 100-mL Erlenmeyer flask. The mixtures are called ASTM color mixed dye solutions M1, M3, M5, and M7.

X1.5.1.5 *Preparation and Verification of the ASTM Color Standard Samples*:

(a) Measure the specified quantity of the ASTM color mixed dye solution as shown in Table X1.5, and place it in a 50 mL beaker. Add 20 mL dodecane and mix. Then place them in a 250-mL volumetric flask. Add dodecane to the marked line, and mix well.

(b) Measure the transmittance between 380–780 nm of the four solutions prepared in X1.5.5.1 using a spectrophotometer (wavelength width: 5 nm, cell: 33 mm).

(c) According to Practice E 308, calculate the tristimulus value Y of the XYZ color system and chromaticity coordinates x, y, and z from the measured spectral transmittance (the value of 5 nm interval) by using the values for CIE Standard Illuminant C and the 1931 Standard Observer. When the values of Y, x, y, and z meet the specifications in Table X1.6, they then can be used as ASTM color standard sample , , , or . The ASTM colors of these color standard samples are called 1.0, 3.0, 5.0, and 7.0, respectively. If the values of Y, x, y, and z do not meet the specifications in Table X1.6, repeat the above procedures.

X1.5.1.6 When putting the ASTM color standard samples in 33-mm cells, the resulting ASTM color standard samples A1, A3, A5, and A7 correspond to the ASTM color 1.0, 3.0, 5.0, and 7.0 of the color standard glasses defined in the test method.

X1.5.1.7 *Storage of the Color Standard Samples*—The Saybolt color standard samples and the ASTM color standard samples prepared shall be kept in brown bottles with screw lids. The bottles shall be wrapped with black bags and then stored in a cool and dark place.

(a) Routine Inspection of the Color Standard Samples—The stored color standard samples shall be routinely inspected for possible deterioration. Use the procedure described in X1.5.3 for inspecting the Saybolt color standard samples and the procedures described in X1.5.5 for ASTM color standard samples. Do not use the sample when the results of the inspection show that the stimulus value Y of the color standard sample and chromaticity coordinates x and y do not meet the specifications in Table X1.3, for the Saybolt color standard sample, or the specifications in Table X1.6, for the ASTM color standard samples.

TABLE X1.3 Specifications for Saybolt Color Standard Samples

Saybolt Color	Saybolt Color, Standard Samples	Stimulus Value, Y	Chromaticity Coordinates		
			x	y	z
+30	S+30	93.0–99.0	0.311–0.316	0.321–0.326	0.358–0.368
+25	S+25	92.0–98.0	0.316–0.322	0.327–0.335	0.343–0.357
+19	S+19	91.0–97.0	0.325–0.332	0.342–0.350	0.318–0.333
+15	S+15	89.0–96.0	0.337–0.342	0.358–0.365	0.298–0.305
+12	S+12	87.0–92.0	0.342–0.348	0.366–0.373	0.279–0.297
0	S0	83.0–89.0	0.376–0.383	0.411–0.419	0.198–0.213
−15	S−15	77.0–84.0	0.418–0.426	0.460–0.466	0.108–0.122

TABLE X1.4 Specifications for ASTM Color Mixed Dye Solution

Dye Solution	ASTM Color Mixed Dye Solution			
	M1	M3	M5	M7
Yellow 5GS-EX	42.000 ± 0.010	40.000 ± 0.01	40.000 ± 0.010	36.600 ± 0.010
Orange EX	5.200 ± 0.005	5.800 ± 0.005	11.600± 0.005	10.600 ± 0.005
Blue SB	0.400 ± 0.001	0.400± 0.001	...	0.200 ± 0.001
Red 5B-SP	...	1.400 ± 0.001	2.000 ± 0.001	2.600 ± 0.001
Violet 3R	2.600 ± 0.001	1.200 ± 0.001	3.200± 0.001	2.200 ± 0.001
Violet B-2R	...	0.800 ± 0.001	1.600 ± 0.001	3.200 ± 0.001
Green SG	0.600± 0.001	0.800 ± 0.001	1.600± 0.001	0.600 ± 0.001

TABLE X1.5 Specifications for ASTM Color Standard Samples

ASTM Color Standard Sample	ASTM Color Mixed Dye Solution Sample	Quantity Unit, g
A1	M1	2.467 ± 0.001
A3	M3	12.987 ± 0.006
A5	M5	23.956 ± 0.010
A7	M7	41.822 ± 0.020

TABLE X1.6 Specifications for ASTM Color Standard Samples A1, A3, A5, and A7

ASTM Color	ASTM Color, Standard Samples	Stimulus Value, Y	Chromaticity Coordinates		
			x	y	z
1.0	A1	71.0–83.0	0.390–0.402	0.427–0.439	0.149–0.183
3.0	A3	27.0–35.0	0.533–0.545	0.449–0.461	0.000–0.019
5.0	A5	6.9–9.3	0.616–0.628	0.372–0.384	0.000–0.013
7.0	A7	1.2–2.0	0.684–0.696	0.303–0.315	0.000–0.012

X2. BASIC CALIBRATION PROCEDURE

X2.1 Measurement of Saybolt Color

X2.1.1 The apparatus used shall meet the specifications outlined in 6.1 through 6.1.3.

X2.1.1.1 *Deriving the Calibration Curve*—Measurement of tristimulus values of Saybolt color standard samples.

(*a*) Perform the set-up, calibration, and standardization of the instrument as specified by the instrument manufacturer.

(*b*) Fill a cell with dodecane and obtain the tristimulus values (see X1.4.3).

NOTE X2.1—Although it is not imperative, it is recommended that the cell have a path length of 100 mm. A cell with a shorter path length may not provide the desired sensitivity.

(*c*) Repeat the above procedure for each of the Saybolt color standard samples. (See X1.5.1.1 (*c*)).

X2.1.1.2 *Conversion From the Tristimulus Values of Saybolt Color Standard Samples to the Saybolt Color Number*

(a) The respective psychrometric index L^* and the psychromatic chroma coordinates a^* and b^* of the CIE 1976 $L^*a^*b^*$ opponent-color scales are calculated from the tristimulus values of the dodecane and the tristimulus values of the Saybolt color standard sample according to the following equations as referenced in Practice E 308:

$$L^* = 116\,(Y/100)^{1}/_{3} - 16 \quad \text{(X2.1)}$$

$$a^* = 500\,[(X/98.072)^{1}/_{3} - (Y/100)^{1}/_{3}] \quad \text{(X2.2)}$$

$$b^* = 200\,[(Y/100)^{1}/_{3} - (Z/118.225)^{1}/_{3}] \quad \text{(X2.3)}$$

where:

X, Y, and Z are the tristimulus values of the dodecane or the Saybolt color standard sample.

(*b*) The color difference ΔE^*ab between the dodecane and Saybolt color standard sample is computed according to the following equation:

$$\Delta E^*ab = [(L^*_1 - L^*_0)^2 + (a^*_1 - a^*_0)^2 + (b^*_1 - b^*_0)^2]^{1/2} \quad \text{(X2.4)}$$

where:

ΔE^*ab = color difference between the Saybolt color standard sample and the dodecane,
L^*_1 = psychrometric lightness of the Saybolt color standard sample,
a^*_1, b^*_1 = psychrometric chroma coordinates of the Saybolt color standard sample,
L^*_0 = psychrometric lightness of the dodecane, and
a^*_0, b^*_0 = psychrometric chroma coordinates of the dodecane.

A calibration curve is derived by plotting the color difference (ΔE^*ab) versus the Saybolt color number.

(*c*) The following equation applies to cells having an optical path length of 100 mm:

$$S = \alpha + \beta/(\log \Delta E^*ab - \tau) \quad \text{(X2.5)}$$

where:

S = Saybolt color number,
ΔE^*ab = color difference between Saybolt color standard sample and dodecane,
α = intercept correction constant (typical = 51.1),
β = slope correction constant (typical = 44.5), and
τ = correction constant (typical = 2.55).

X2.1.1.3 *Procedure for Measuring the Saybolt Color Number of the Test Sample:*

(a) The test sample is obtained by using the sampling method of secondary sample prescribed in Practice D 4057 or a method that complies with such.

(b) When the sample is cloudy, filter the sample while changing the qualitative filter paper until the cloudiness is no longer present.

(c) Obtain the tristimulus values of the test sample and convert them to $L^*a^*b^*$ values as outlined in X2.1.1.1 (*b*)–X2.1.1.2. Then, using Eq X2.4, compute the ΔE^*ab between the dodecane and the test sample.

(d) Determine the Saybolt color number of the sample to one decimal place from the color difference obtained above using the calibration curve prepared in X2.1.1.2.

X2.2 Measurement of ASTM Color

X2.2.1 *Preparation of Calibration Curve*—Measurement of tristimulus values of ASTM color standard sample.

X2.2.1.1 Perform the set-up, calibration, and standardization of the instrument as specified by the instrument manufacturer.

X2.2.1.2 Fill a cell with an ASTM color standard sample and obtain the tristimulus values (see X1.5.1.5 (*b*) and (*c*).

NOTE X2.2—Although it is not imperative, it is recommended that the cell have a path length of 33 mm. A cell with a different path length may not provide the desired sensitivity.

X2.2.1.3 Repeat the above procedure for each of the ASTM color standard samples (see X1.5.1.5).

X2.2.2 *Conversion From Tristimulus Values to ASTM Color*:

X2.2.2.1 The sum of the optical densities ΣD is computed from the tristimulus values of the ASTM color standard sample using the following equation:

$$\Sigma D = DX + DY + DZ \quad \text{(X2.6)}$$

where:

ΣD = sum of optical densities,
DX = $-\log_{10}(X/X_n)$,
DY = $-\log_{10}(Y/Y_n)$,
DZ = $-\log_{10}(Z/Z_n)$,
X, Y, Z = tristimulus values of ASTM color standard sample, and
X_n, Y_n, Z_n = tristimulus values of Standard Illuminant C.
X_n = 98.072,
Y_n = 100.000, and
Z_n = 118.225.

X2.2.2.2 A calibration curve is developed by plotting the sum of the optical densities of the ASTM color standard samples versus the ASTM color number. The relationship between ASTM color number and the sum of the optical densities can be determined according to the following equation:

$$A = \alpha + \beta \times \Sigma D \quad \text{(X2.7)}$$

where:

A = ASTM color number,
ΣD = sum of optical densities,
α = intercept correction constant (typical = 0.25), and
β = slope correction constant (typical = 0.8695).

X2.2.3 *Procedure for Measuring the ASTM Color of the Sample*:

X2.2.3.1 The sample for test is obtained by using the sampling method of secondary sample prescribed in Practice D 4057 or a method that complies with such.

X2.2.3.2 Obtain the tristimulus values of the test sample (see X2.2.1.2) and convert them to the sum of the optical densities as outlined in X2.2.2.1.

X2.2.3.3 Determine the ASTM color of the sample to one decimal place from the calibration curve prepared in X2.2.2.2.

X2.2.3.4 If the ASTM color number of the sample exceeds eight, dilute the sample with diluent and use this mixture as the measurement sample. At this time, the mixing ratio of sample to diluent shall be 15:85 with respect to volume ratio.