Designation: D5797 – 16

Standard Specification for
Methanol Fuel Blends (M51–M85) for Methanol-Capable Automotive Spark-Ignition Engines[1]

This standard is issued under the fixed designation D5797; 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 specification covers the requirements for automotive fuel blends of methanol and gasoline for use in ground vehicles equipped with methanol-capable flexible-fuel, and dedicated methanol spark-ignition engines. Fuel produced to this specification contains 51 % to 85 % by volume methanol. This fuel is sometimes referred to at retail as "M85." Appendix X1 discusses the significance of the properties specified. Appendix X2 presents the current status in the development of a luminosity test procedure (flame visibility) for methanol fuel blends (M51–M85).

1.2 The vapor pressure of methanol fuel blends is varied for seasonal climatic changes. Vapor pressure is increased at lower temperatures to ensure adequate vehicle operability and safety. Methanol content and selection of gasoline blendstocks are adjusted by the blender to meet these vapor pressure requirements.

1.3 The United States government has established various programs for alternative fuels. Many of the definitions of alternative fuel used by these programs can be more or less restrictive than the requirements of this specification. See Annex A1 for additional information on alternative fuels containing methanol.

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

1.4.1 *Exception*—Non-SI units are provided for information only. In most cases, U.S. federal regulations specify non-SI units.

1.5 The following precautionary caveat pertains only to the test method portions–Appendix X2 of this specification. *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:*[2,3]

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D381 Test Method for Gum Content in Fuels by Jet Evaporation
D525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)
D1193 Specification for Reagent Water
D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)
D1613 Test Method for Acidity in Volatile Solvents and Chemical Intermediates Used in Paint, Varnish, Lacquer, and Related Products
D3231 Test Method for Phosphorus in Gasoline
D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products
D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
D4806 Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel
D4814 Specification for Automotive Spark-Ignition Engine Fuel
D4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)
D5059 Test Methods for Lead in Gasoline by X-Ray Spectroscopy
D5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)

---

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is under the direct responsibility of Subcommittee D02.A0.02 on Oxygenated Fuels and Components.

Current edition approved April 1, 2016. Published April 2016. Originally approved in 1995. Last previous edition approved in 2015 as D5797 – 15. DOI: 10.1520/D5797-16.

[2] Reference to the following documents is to be the latest issue unless otherwise specified.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

D5453 Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence

D5798 Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines

D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products

D7328 Test Method for Determination of Existent and Potential Inorganic Sulfate and Total Inorganic Chloride in Fuel Ethanol by Ion Chromatography Using Aqueous Sample Injection

D7667 Test Method for Determination of Corrosiveness to Silver by Automotive Spark-Ignition Engine Fuel—Thin Silver Strip Method

D7671 Test Method for Corrosiveness to Silver by Automotive Spark–Ignition Engine Fuel–Silver Strip Method

D7757 Test Method for Silicon in Gasoline and Related Products by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry

D7920 Test Method for Determination of Fuel Methanol (M99) and Methanol Fuel Blends (M10 to M99) by Gas Chromatography

E203 Test Method for Water Using Volumetric Karl Fischer Titration

3. Terminology

3.1 For general terminology, refer to Terminology D4175.

3.2 *Definitions:*

3.2.1 *aliphatic ether, n*—an oxygen-containing, ashless, organic compound in which the oxygen atom is interposed between two carbon atoms (organic groups), has the general formula $C_nH_{2n+2}O$ with n being 5 to 8, and in which the carbon atoms are connected in open chains and not closed rings.

3.2.1.1 *Discussion*—Aliphatic compounds can be straight or branched chains and saturated or unsaturated. The term aliphatic ether, as used in this specification, refers only to the saturated compounds.

3.2.2 *denatured fuel ethanol, n*—ethanol made unfit for beverage use by the addition of denaturants under formula(s) approved by the applicable regulatory agency to prevent the imposition of beverage alcohol tax. **D4806**

3.2.3 *ethanol, n*—ethyl alcohol, the chemical compound C_2H_5OH. **D4806**

3.2.4 *finished fuel, n*—a homogeneous mixture of blendstocks and fuel additives meeting all specification and regulatory requirements for its intended use at the location where sold.

3.2.5 *fuel methanol (M99), n*—methanol with small/trace alcohol and hydrocarbon impurities.

3.2.6 *gasoline, n*—volatile mixture of liquid hydrocarbons, generally containing small amounts of additives, suitable for use as a fuel in spark-ignition, internal combustion engines. **D4814**

3.2.7 *gasoline blendstock, n*—a liquid hydrocarbon component suitable for use in spark-ignition engine fuels.

3.2.7.1 *Discussion*—Examples of gasoline blendstock include natural gasoline, raffinate, reformate, naphtha, conventional gasoline blendstock for oxygenated blending (CBOB), and reformulated gasoline blendstock for oxygenate blending (RBOB).

3.2.8 *higher alcohols*—aliphatic alcohols of the general formula $C_nH_{2\ n+1}OH$ with n being 2 to 8.

3.2.9 *hydrocarbon*—a compound composed solely of hydrogen and carbon.

3.2.10 *methanol, n*—methyl alcohol, the chemical compound CH_3OH.

3.2.11 *methanol fuel blend (M51–M85), n*—a blend of methanol and hydrocarbons of which the methanol portion is nominally 51 % to 85 % by volume.

3.2.11.1 *Discussion*—In the abbreviation, MXX, the XX represents the volume percentage of methanol in the fuel blend.

4. Ordering Information

4.1 The purchasing agency shall:

4.1.1 Indicate the season and locality in which the fuel is to be used,

4.1.2 If requested, ensure that the methanol concentration meets the requirements for an alternative fuel for United States federal fleets.

4.1.3 For further information, see Annex A1 of this specification.

5. Methanol Fuel Blends Performance Requirements

5.1 Methanol fuel blends shall conform to the requirements in Table 1.

NOTE 1—Most of the requirements cited in Table 1 are based on the best technical information currently available. As greater experience is gained from field use of methanol-capable vehicles, some of these requirements will change.

5.1.1 The components used to produce methanol fuel blends are limited to methanol and gasoline blendstock as defined in 5.2.

5.1.2 The intentional addition of lead or phosphorus compounds to methanol fuel blends is not permitted.

5.2 Gasoline blendstocks used shall meet the requirements of Table 2. The gasoline blendstock may contain aliphatic ethers as blending components that are used in automotive fuels in some countries outside of North America.

5.3 Vapor pressure is varied for seasonal and climatic changes by providing three vapor pressure classes for methanol fuel blends as follows:

(1) Class 1 encompasses geographical areas with 6 h tenth-percentile minimum ambient temperature of greater than 5 °C (41 °F).

(2) Class 2 encompasses geographical areas with 6 h tenth-percentile minimum temperatures of greater than –5 °C (23 °F) but less than or equal to 5 °C (41 °F).

(3) Class 3 encompasses geographical areas with 6 h tenth-percentile minimum ambient temperature less than or equal to –5 °C (23 °F).

5.3.1 There is a 10 % probability that the highest temperature of the six coldest consecutive hourly temperature readings

TABLE 1 Requirements for Methanol Fuel Blends (M51–M85)

Properties	Class 1[A]	Class 2	Class 3	Test Methods Annex A1 D4953 or D5191
Vapor pressure, kPa[B] (psi)	48–62 (7.0–9.0)	62–83 (9.0–12.0)	83–103 (12.0–15.0)	
		All Classes[C]		
Methanol Content, % by volume, min		51–85		D7920
Lead, mg/L, max		2.6		D5059[D]
Phosphorus, mg/L, max		0.2		D3231
Sulfur, mg/kg, max		80		D5453
Acidity, as acetic acid, mg/kg, max		50		D1613
Unwashed gum content, mg/100 mL, max		20		D381
Solvent washed gum content, mg/100 mL, max		5		D381
Total Inorganic Sulfate, mg/kg, max		4		D7328
Water, % by mass, max		0.5		E203
Total Inorganic Chloride, mg/kg, max		1		D7328

[A] See 5.3 for volatility class criteria.

[B] The vapor pressure overlap is intentional to cover changes associated with seasonal changes.

[C] Methanol content and selection of gasoline blendstock are adjusted by the blender to meet vapor pressure requirements. See X1.3.3 for additional information and guidance for blending.

[D] With Test Methods D5059, prepare the calibration standards using methanol (reagent grade) as the solvent to prevent errors caused by large differences in carbon-hydrogen ratios.

TABLE 2 Requirements for Gasoline Blendstock

Properties		Test Methods
Distillation, end point, °C(°F), max	225 (437)	D86
Oxidation stability, minutes, min	240	D525
Copper strip corrosion, max	No. 1	D130
Silver strip corrosion, max	No. 1	D7667, D7671
Vapor pressure, kPa	Report[A]	D4953, D5191

[A] While not a requirement of this specification, the blender will need to know the vapor pressure of the gasoline blendstock in order to choose a suitable blend ratio for the components to meet the vapor pressure requirement of a particular volatility class.

of a 24 h day will be colder than the 6 h tenth percentile minimum ambient temperature.

5.3.2 See 5.4.2 for seasonal and geographical distributions in the United States.

5.4 *Regulatory and Other Requirements in the United States:*

5.4.1 Methanol content and other requirements for methanol alternative fuel blends in the United States can be found in Annex A1 of this standard.

5.4.2 The United States seasonal and geographical distribution for the three vapor pressure classes is shown in Annex A1, Table A1.1.

5.5 *Regulatory and Other Requirements Outside the United States:*

5.5.1 Users of this specification are advised to consult with the applicable regulatory agency for specific requirements for their jurisdictions.

5.5.2 Users of the specification in geographical areas outside the United States need to determine the 6 h tenth percentile minimum ambient temperatures for their geographic areas and times of year in order to select the appropriate classes of fuel.

5.6 Use of unprotected aluminum in methanol fuel blend distribution and dispensing equipment will introduce insoluble aluminum compounds into the fuel causing plugged vehicle fuel filters. Furthermore, this effect can be exaggerated even with protected aluminum by elevated fuel conductivity caused by contact with a nitrile rubber dispensing hose. Therefore, unprotected aluminum and an unlined nitrile rubber dispensing hose should be avoided in methanol fuel blend distribution and dispensing systems.[4,5]

6. Workmanship

6.1 The finished fuel blend shall be visually free of sediment, suspended, or undissolved matter. It shall be clear and bright at the fuel temperature at the point of custody transfer or at a lower temperature agreed upon by the purchaser and seller.

NOTE 2—Finished fuel should be resistant to phase separation or undissolved matter at the lowest temperatures to which it is likely to be subjected, dependent on the time and place of its intended use. See Specification D4814, Table X7.1 for guidance.

NOTE 3—Solubility is temperature dependent. As this fuel cools, some high molecular weight additives can become insoluble.

6.2 The specification defines only a basic purity for methanol fuel blend (M51–M85). The product shall be free of any adulterant or contaminant that can render the material unacceptable for its commonly used applications.

6.2.1 Manufacturers and blenders of methanol fuel blend (M51–M85) shall avoid methanol (for example, improperly recycled methanol), or hydrocarbon blend components contaminated by silicon-containing materials, or both. Silicon contamination of gasoline, denatured ethanol, and their blends has led to fouled vehicle components (for example, spark plugs, exhaust oxygen sensors, catalytic converters) requiring parts replacement and repairs. Test Method D7757 is a procedure for determining silicon that might be applicable to methanol fuel blend (M51–M85). No specification limits have been established for silicon.

---

[4] California Energy Commission, "Fifteen Years of Fuel Methanol Distribution," http://www.methanol.org/Energy/Resources/Alternative-Fuel/CEC- 1996-ISAF-Fuel-Meoh-Paper.aspx

[5] California Air Resources Board, Methanol Fuel Additive Demonstration, http://arb.ca.gov/research/apr/past/a832-123a

7. Sampling, Containers, and Sample Handling

7.1 The reader is strongly advised to review all intended test methods prior to sampling to better understand the importance and effects of sampling technique, proper containers, and special handling required for each test method.

7.2 Correct sampling procedures are critical to obtain a sample representative of the lot intended to be tested. Use appropriate procedures in Practice D4057 for manual method sampling and in Practice D4177 for automatic sampling as applicable.

7.3 The correct sample volume and appropriate container selection are important decisions that can impact test results. Refer to Practice D4306 for aviation fuel container selection for tests sensitive to trace contamination. Refer to Practice D5854 for procedures on container selection and sample mixing and handling. Where practical, methanol fuel blends should be sampled in amber borosilicate glass containers. If samples must be collected in metal containers, do not use soldered metal containers. The soldering flux in the containers and the lead in the solder can contaminate the sample. Plastic containers should be avoided.

7.4 A minimum sample size of about 1 L (~1 qt) is recommended.

8. Test Methods

8.1 Determine the requirements enumerated in this specification in accordance with the following test methods:

NOTE 4—The appropriateness of ASTM test methods cited has not been demonstrated for use with M51–M85. In addition, test methods contained in the annexes and appendixes are in the developmental stages or lack precision and bias determinations.

8.1.1 *Vapor Pressure*—Test Methods D4953 or D5191.

8.1.2 *Methanol Content*—Test Method D7920.

8.1.3 *Lead*—Test Methods D5059. With Test Methods D5059, prepare the calibration standards using methanol (reagent grade) as the solvent to prevent errors caused by large differences in carbon-hydrogen ratios.

8.1.4 *Phosphorus*—Test Method D3231.

8.1.5 *Sulfur*—Test Methods D1266 or D5453.

8.1.6 *Acidity*—Test Method D1613.

8.1.7 *Gum Content, Solvent Washed and Unwashed*—Test Method D381.

8.1.8 *Total Sulfates*—Test Method D7328.

8.1.9 *Water*—Test Method E203.

8.1.10 *Total Inorganic Chloride*—Total inorganic chloride may be determined by a modification of Test Method D7328, a standard test method for determination of total inorganic chloride in fuel ethanol by ion chromatography using aqueous sample injection. Refer to Test Method D7328 for terminology, equipment required, reagents and solutions, calibration procedures, and general procedure for the determination of total inorganic chloride in fuel ethanol. Note that although Test Method D7328 is also the standard test method for determination of existent and potential inorganic sulfate in fuel ethanol, that determination is addressed separately in Specification D5797, the standard specification for methanol fuel blends. The procedure for total inorganic chloride determination will be summarized:

8.1.10.1 Obtain a well-mixed homogeneous sample of methanol fuel blend in a glass container, equipped with closures that can be well-sealed, and free of any residual or extractable chloride. If containers have been cleaned and rinsed with water, they should be thoroughly rinsed with Type II or better reagent water according to Specification D1193 and dried prior to use.

8.1.10.2 Thoroughly mix the sample in its container immediately prior to withdrawal of the test specimen.

8.1.10.3 Set up the ion chromatograph in accordance with the manufacturer's instructions.

8.1.10.4 Equilibrate the system by pumping eluent for 15 min to 30 min, until a stable baseline is obtained.

8.1.10.5 Start the chromatographic run in accordance with manufacturer's instructions.

8.1.10.6 Carefully add 2.00 mL of the methanol fuel blend test specimen into a clean, dry, tared 15 mL glass vial without its screw cap closure.

8.1.10.7 Place the vial with sample in a hot block at 65 °C and blow a steady stream of nitrogen gas over the sample at 2 mL/min to 3 mL/min flowrate. Maintain these conditions for 15 min. Remove the vial from the hot block and allow it to cool to room temperature 15 °C to 27 °C. Note that it is probable that a small amount of liquid remains. Do not worry about this residue since any inorganic chloride will be extracted into the water phase.

8.1.10.8 Carefully add 2.00 mL of Type II or better water to the dried sample. Seal the vial with a screw cap, and shake the vial vigorously to dissolve all of the solid salts.

8.1.10.9 If an emulsion results after these steps, pass the liquid through a column or cartridge designed specifically to remove hydrocarbons from liquids prior to injecting them in an ion chromatograph.

8.1.10.10 Inject 25 µL of the resulting clear solution or eluent into the ion chromatograph, and measure the area of the peak corresponding to chloride ion.

8.1.10.11 Calculate the concentration of inorganic chloride in the original sample according to the procedures shown in Section 12 of Test Method D7328.

9. Keywords

9.1 acidity; alcohol; automotive spark-ignition engine fuel; chloride; copper corrosion; ether; fuel methanol (M99); gasoline blendstock; gum content; hydrocarbon; hydrocarbon blendstock; inorganic chloride; lead; methanol; methanol fuel blends (M51–M85); MTBE; oxidation stability; oxygenates; phosphorus; solvent washed; sulfur; vapor pressure; volatility; water

ANNEX

(Mandatory Information)

A1. INFORMATION SPECIFIC TO THE UNITED STATES

A1.1 The composition of alternative fuels in the United States is regulated by various government agencies and regulations including the U.S. Department of Energy (DOE) and U.S Environmental Protection Agency (EPA). With regard to fuel properties including volatility, this specification can be more or less restrictive than DOE or EPA rules, regulations and waivers. To qualify as an alternative fuel for federal fleet use in the United States, methanol fuel blends are required to meet the U.S. Department of Energy's definition of alternative fuels, enacted under the Energy Policy Act of 1992 (Title III, Sec. 301). For methanol, the Act defines "alternative fuel" as "mixtures containing 85 % or more (or such other percentage, but not less than 70 %, as determined by the Secretary, by rule, to provide for requirements to cold start, safety, or vehicle functions) by volume of methanol." The U.S. government has other programs and definitions for alternative fuels. Users of this specification are advised to check with the applicable regulatory agency for specific alternative fuel requirements.

A1.2 Methanol fuel blends of any volatility class shall meet the same limits for lead and phosphorus as required by U.S. Environmental Protection Agency (EPA) regulations for unleaded gasoline. EPA regulations limit "the maximum concentration of lead in unleaded gasoline to 0.013 g/L(0.05 g lead/US gal) and the maximum concentration of phosphorus in unleaded gasoline to 0.0013 g/L (0.005 g/US gal), respectively." Details of the EPA regulations and test methods are available in the United States Code of Federal Regulations, Title 40, Part 80.

A1.3 Table A1.1 provides the United States seasonal and geographical volatility specifications for methanol fuel blends.

TABLE A1.1 United States Seasonal and Geographical Volatility Specifications for Methanol Fuel Blends (M51-M85)

NOTE 1—This schedule is subject to agreement between the purchaser and the seller denotes the vapor pressure class of the fuel at the time and place of bulk delivery to fuel dispensing facilities for the end user. Shipments should anticipate this schedule.

NOTE 2—Where alternative classes are listed, either class is acceptable; the option shall be exercised by the seller.

NOTE 3—This schedule was developed using actual (versus altitude-adjusted) 6 h tenth percentile minimum ambient temperatures

State	January	February	March	April	May	June	July	August	September	October	November	December
Alabama	2	2	2	2	2/1	1	1	1	1	1/2	2	2
Alaska												
Southern Region	3	3	3	3/2	2	2/1	1	1/2	2/3	3	3	3
South Mainland	3	3	3	3	3/2	2	2/1	2	2/3	3	3	3
Arizona												
N of 34° Latitude	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
S of 34° Latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Arkansas	3	3	3/2	2/1	1	1	1	1	1/2	2	2/3	3
California[A]												
North Coast	2	2	2	2	2/1	1	1	1	1	1/2	2	2
South Coast	2	2	2	2	2/1	1	1	1	1	1/2	2	2
Southeast	2	2	2	2	2/1	1	1	1	1	1/2	2	2
Interior	2	2	2	2	2	2/1	1	1	1	1/2	2	2
Colorado												
E of 105° Longitude	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
W of 105° Longitude	3	3	3	3	3/2	2	2/1	1/2	2/3	3	3	3
Connecticut	3	3	3	3/2	2	2/1	1	1	1/2	2	2/3	3
Delaware	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
District of Columbia	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Florida												
N of 29° Latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
S of 29° Latitude	2	2/1	1	1	1	1	1	1	1	1	1/2	2
Georgia	3	3/2	2	2/1	1	1	1	1	1	1/2	2	2/3
Hawaii	1	1	1	1	1	1	1	1	1	1	1	1
Idaho	3	3	3	3/2	2	2	2/1	1/2	2	2/3	3	3
Illinois												
N of 40° Latitude	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
S of 40° Latitude	3	3	3	3/2	2/1	1	1	1	1/2	2/3	3	3
Indiana	3	3	3	3/2	2/1	1	1	1	1/2	2/3	3	3
Iowa	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
Kansas	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
Kentucky	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Louisiana	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Maine	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
Maryland	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Massachusetts	3	3	3	3/2	2	2/1	1	1	1/2	2	2/3	3
Michigan												
Lower Michigan	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
Upper Michigan	3	3	3	3	3/2	2/1	1	1/2	2	2/3	3	3
Minnesota	3	3	3	3	3/2	2/1	1	1/2	2	2/3	3	3
Mississippi	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Missouri	3	3	3	3/2	2/1	1	1	1	1/2	2/3	3	3
Montana	3	3	3	3	3/2	2	2/1	1/2	2/3	3	3	3
Nebraska	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
Nevada												
N of 38° Latitude	3	3	3	3/2	2	2	2/1	1/2	2	2/3	3	3
S of 38° Latitude	2	2	2	2	2/1	1	1	1	1	1/2	2	2
New Hampshire	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
New Jersey	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
New Mexico												
N of 34° Latitude	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
S of 34° Latitude	3	3	3/2	2/1	1	1	1	1	1	1/2	2/3	3
New York												
N of 42° Latitude	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
S of 42° Latitude	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
North Carolina	3	3	3/2	2	2/1	1	1	1	1/2	2/3	3	3
North Dakota	3	3	3	3	3/2	2/1	1	1/2	2	2/3	3	3
Ohio	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
Oklahoma	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
Oregon												
E of 122° Longitude	3	3	3	3/2	2	2	2/1	1/2	2	2/3	3	3
W of 122° Longitude	3	3/2	2	2	2	2/1	1	1	1/2	2	2	2/3
Pennsylvania												
N of 41° Latitude	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
S of 41° Latitude	3	3	3	3/2	2	2/1	1	1	1/2	2	2/3	3
Rhode Island	3	3	3	3/2	2/1	1	1	1	1/2	2	2/3	3
South Carolina	2	2	2	2/1	1	1	1	1	1	1/2	2	2
South Dakota	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3

TABLE A1.1 *Continued*

State	January	February	March	April	May	June	July	August	September	October	November	December
Tennessee	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Texas												
N of 31° Latitude	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
S of 31° Latitude	2	2	2	2/1	1	1	1	1	1	1/2	2	2
Utah	3	3	3	3/2	2	2/1	1	1	1/2	2/3	3	3
Vermont	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
Virginia	3	3	3/2	2	2/1	1	1	1	1/2	2	2/3	3
Washington												
E of 122° Longitude	3	3	3	3/2	2	2	2/ 1	1	1/2	2/3	3	3
W of 122° Longitude	3	3/2	2	2	2	2/1	1	1	1/2	2	2	2/3
West Virginia	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
Wisconsin	3	3	3	3/2	2	2/1	1	1/2	2	2/3	3	3
Wyoming	3	3	3	3	3/2	2	2/1	1/2	2	2/3	3	3

[A] Details of State Climatological Division by county as indicated:

California, North Coast—Alameda, Contra Costa, Del Norte, Humbolt, Lake, Marin, Mendocino, Monterey, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma, Trinity

California, Interior—Lassen, Modoc, Plumas, Sierra, Siskiyou, Alpine, Amador, Butte, Calaveras, Colusa, El Dorado, Fresno, Glenn, Kern (except that portion lying east of Los Angeles County Aqueduct), Kings, Madera, Mariposa, Marced, Placer, Sacramento, San Joaquin, Shasta, Stanislaus, Sutter, Tehama, Tulare, Tuolumne, Yolo, Yuba, Nevada

California, South Coast—Orange, San Diego, San Luis Obispo, Santa Barbara, Ventura, Los Angeles (except that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct)

California, Southeast—Imperial, Riverside, San Bernadino, Los Angeles (that portion north of the San Gabriel Mountain range and east of the Los Angeles County Aqueduct), Mono, Inyo, Kern (that portion lying east of the Los Angeles County Aqueduct)

APPENDIXES

(Nonmandatory Information)

X1. SIGNIFICANCE OF STANDARD FOR METHANOL FUEL BLENDS (M51–M85) FOR METHANOL-CAPABLE AUTOMOTIVE SPARK-IGNITION ENGINES

X1.1 Methanol

X1.1.1 The methanol content of M51–M85 is a crucial parameter as it affects the capability of the fuel metering system of the methanol capable vehicle to establish the proper air-fuel ratio for optimum vehicle operation. This is much less of a concern for multi-fuel-capable vehicles than for dedicated methanol vehicles. Methanol content affects the lubrication properties of the fuel and affects the water tolerance of the methanol fuel blend.

X1.1.2 The inclusion of impurities and contaminants, except for the deliberately added hydrocarbons or additives, or both, can impact adversely on the properties and performance of methanol fuel blends as an automotive spark-ignition engine fuel. The quantities of some of these materials are limited by specified property limits. Trace amounts of unspecified materials including higher alcohols, methyl formate, acetone, and dimethyl ether can be present. The maximum limit on water, the maximum limit on higher alcohols, and minimum-maximum limits on hydrocarbon/aliphatic ether content control the amount of some impurities and contaminants.

X1.2 Gasoline Blendstock

X1.2.1 Gasoline blendstocks are deliberately added to provide improved cold startability and cold-start and warm-up driveability. The addition of gasoline blendstocks also contributes to flame visibility (luminous flame), nonexplosive air-fuel mixtures in storage tanks (rich mixture vapor space), and denaturation (malodorant and taste deterrent). The gasoline blendstock portion of the fuel must be unleaded.

X1.2.2 Gasoline blendstocks shall be stable, noncorrosive, and be in the boiling range of spark-ignition engine fuel as specified in Table 2 and Specification D4814.

X1.3 Vapor Pressure

X1.3.1 The addition of volatile hydrocarbons improves cold startability. The addition of too much volatile hydrocarbons can cause hot fuel handling problems. When blending with gasoline as the hydrocarbon portion during the wintertime, a higher hydrocarbon content may be necessary to obtain required volatility. Higher vapor pressures are required in the wintertime for cold starting, and lower vapor pressures are needed in the summertime to prevent hot fuel handling problems. Excessive vapor pressure for a given ambient condition can contribute to evaporative emissions. Lower and upper limits on vapor pressure for three volatility classes are used to define the acceptable range of the volatile components to ensure proper vehicle performance.

X1.3.2 Three vapor pressure classes of fuel are provided to satisfy vehicle performance requirements under different climatic conditions. The schedule for seasonal and geographical distribution in Annex A1, Table A1.1, indicates the appropriate vapor pressure class (Class 1 through Class 3) for each month in all areas of the United States, based on altitude and expected air temperatures.

X1.3.3 The following four charts can be used to estimate the vapor pressure of methanol fuel blends. Fig. X1.1 and Fig. X1.2 are in SI units and Fig. X1.3 and Fig. X1.4 are in United

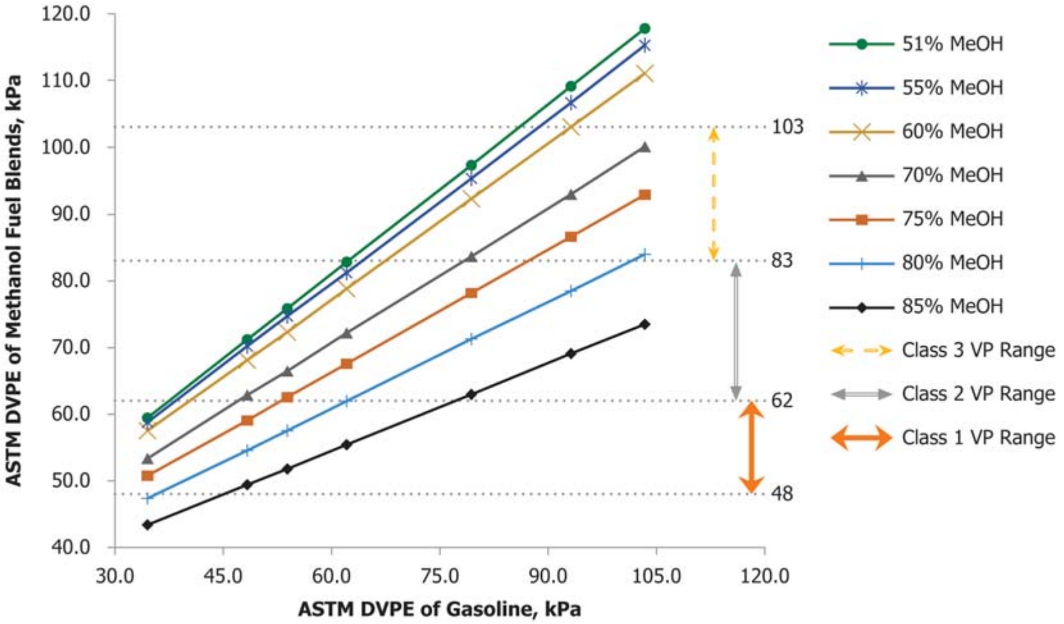

FIG. X1.1 Estimated Methanol Fuel Blend Vapor Pressure as a Function of Gasoline Blendstock Vapor Pressure and Methanol Content, kPA

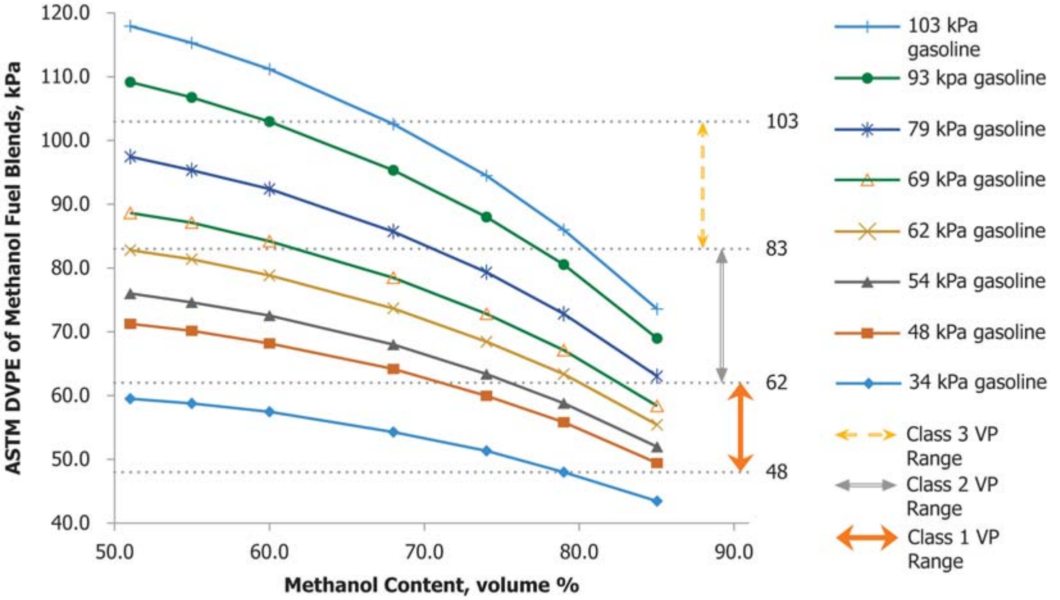

FIG. X1.2 Estimated Methanol Fuel Blend Vapor Pressure as a Function of Methanol Content and Gasoline Blendstock Vapor Pressure, kPA

States customary units. The charts enable blenders who know the vapor pressure of the gasoline blendstock to estimate the correct proportion of gasoline blendstock and methanol to achieve the vapor pressure required in this specification. These curves were developed using the predictive equations found in an SAE paper.[6]

X1.4 Luminosity (Flame Visibility)

X1.4.1 When pure methanol burns, it produces a blue, smokeless, nonluminous flame that is nearly invisible in daylight. Thus, it is difficult to know when a fire exists and to fight such a fire. A desirable property for methanol fuel blends is that it maintain a clearly visible flame throughout the duration of a burn. It would be very hazardous for the visible flame to disappear before the fire was extinguished. For lack of a suitable test method for determining luminosity of methanol fuel blends, luminosity is not controlled by this specification. (See X1.4.3.)

X1.4.2 To make a methanol flame visible, materials such as aromatic hydrocarbons are added to methanol. In general, it has been established that unleaded gasoline having greater than 30 % by volume aromatics content when used as the gasoline

---

[6] Davy, M. H., "Modeling the Effects of Methanol Blending in Gasoline: An Approximate Equation for Blended Reid Vapour Pressure (RVP)," draft, SAE, 2016.

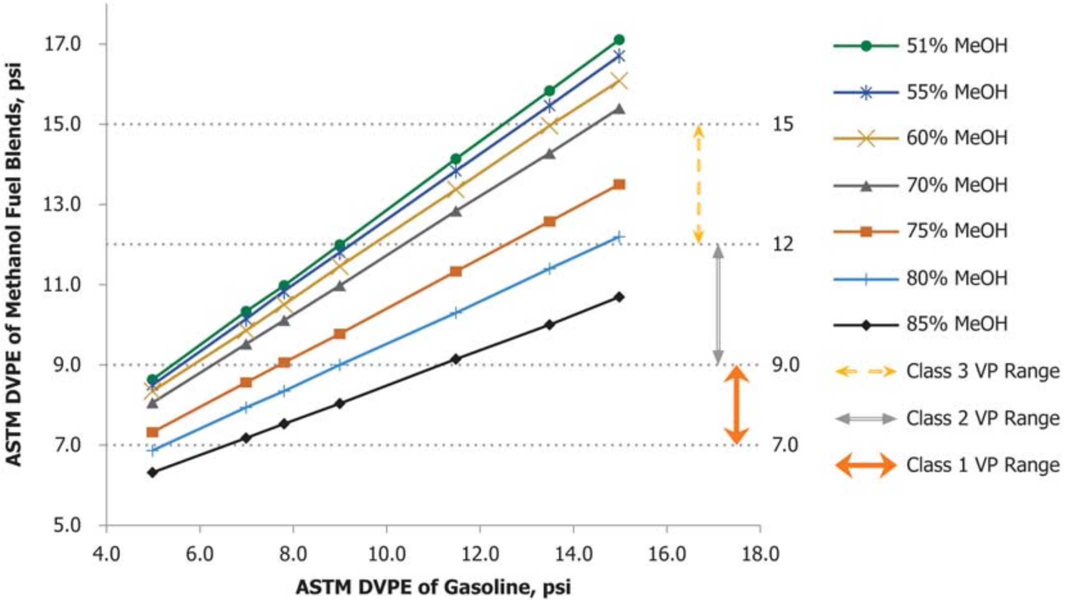

FIG. X1.3 Estimated Methanol Fuel Blend Vapor Pressure as a Function of Gasoline Blendstock Vapor Pressure and Methanol Content, psi

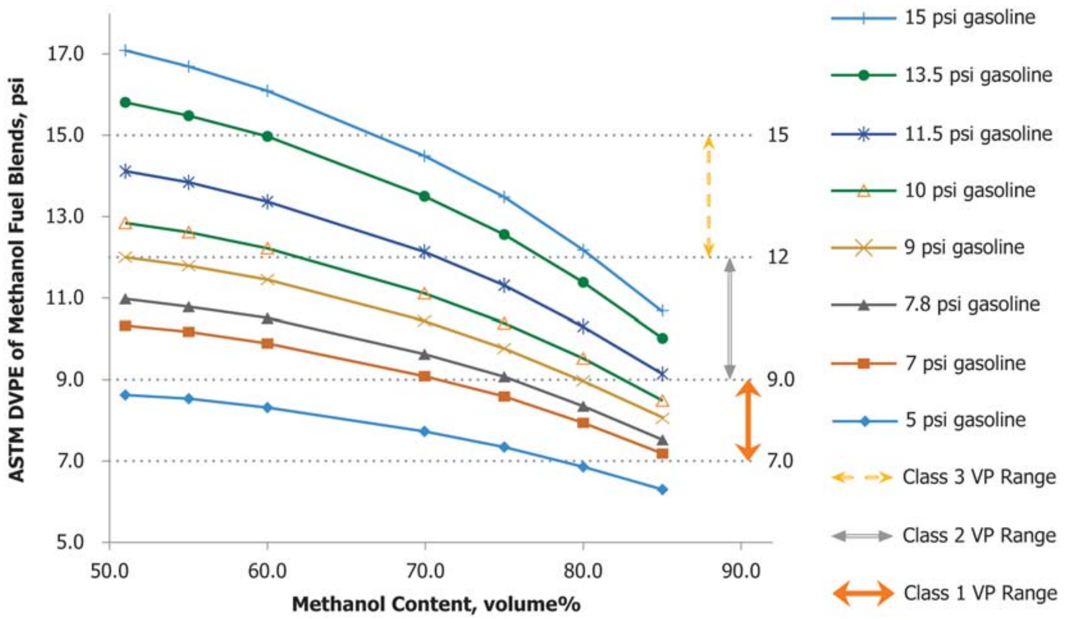

FIG. X1.4 Estimated Methanol Fuel Blend Vapor Pressure as a Function of Methanol Content and Gasoline Blendstock Vapor Pressure, psi

blendstock for blends containing 70 % to 85 % by volume methanol will result in a fuel that will meet a requirement of a clearly visible flame throughout most of a burn. However, the luminosity performance is dependent on the types of aromatics present in the gasoline portion and the volume of blendstock in the methanol fuel blend.

X1.4.3 Appendix X2 contains a suggested procedure for measuring the luminosity of methanol fuel blends. However, lack of a suitable criteria for establishing the relevancy of the procedure makes it unusable as the basis of a specification requirement at this time. It is intended that a test be developed that will ensure adequate luminosity of methanol fuel blends based on performance, rather than on composition.

X1.5 Acidity

X1.5.1 Very dilute aqueous solutions of low molecular weight organic acids such as formic acid are highly corrosive to many metals. It is, therefore, necessary to keep such acids at a very low level.

X1.6 Gum Content, Solvent-Washed and Unwashed

X1.6.1 The test for solvent-washed gum content measures the amount of residue after evaporation of the fuel and following a heptane wash. The heptane wash removes the heptane-soluble, nonvolatile material such as additives, carrier oils used with additives, and diesel fuels. Unwashed gum consists of fuel-insoluble gum and fuel-soluble gum. The fuel-insoluble portion can clog fuel filters. Both can be deposited on surfaces when the fuel evaporates.

X1.6.2 Solvent-washed gum content can contribute to deposits on the surfaces of carburetors, fuel injectors, and intake manifolds, ports, valves, and valve guides. The impact of solvent-washed gum on malfunctions of modern engines which can operate on methanol fuel blends has not been fully established but is based on limited experience gained with methanol fuel blends in field tests and from historic gasoline limits. Performance effects depend on where the deposits form, the presence of other deposit precursors such as airborne debris, blowby and exhaust gas recirculation gases, oxidized engine oil, and the amount of deposit.

X1.6.3 The difference between the unwashed and solvent washed gum content values can be used to assess the presence and amount of nonvolatile material in the fuel. Additional analytical testing is required to determine if the material is additive, carrier oil, diesel fuel, and so forth.

X1.6.4 The unwashed gum content limit is intended to limit high-boiling contaminants, like diesel fuel, that can affect engine performance, yet allow the proper dosage of deposit-control additives with carrier oils normally added to the hydrocarbon portion of the methanol fuel blends.

X1.6.5 Because the precision statements for Test Method D381 were developed using only data on hydrocarbons, they may not be applicable to fuel methanol blends.

X1.7 Total Inorganic Chloride

X1.7.1 Inorganic chloride can be corrosive to many metals. It is desirable to minimize these compounds in methanol fuel blends.

X1.7.2 A total inorganic chloride limit of 1 mg/kg, max, is specified to provide protection.

X1.8 Total Inorganic Sulfate

X1.8.1 Inorganic sulfate salts can precipitate from the fuel and clog filters in the vehicle or distribution system. They can also form fuel injector deposits which can stick injectors or impede fuel flow.

X1.8.2 The total inorganic sulfate limit of 4 mg/kg, max, is specified to provide protection against filter plugging and injector fouling.

X1.9 Lead

X1.9.1 Most modern gasoline-powered vehicles are equipped with exhaust catalytic converters to control emissions of hydrocarbons, carbon monoxide, and oxides of nitrogen. Most methanol-capable vehicles are also equipped with exhaust catalysts that control emissions of formaldehyde as well as the regulated emissions. Lead compounds deactivate the catalysts and are limited to trace amounts to prevent this problem.

X1.10 Phosphorus

X1.10.1 Like lead, phosphorus deactivates exhaust catalysts and is limited to trace amounts.

X1.11 Appearance

X1.11.1 Turbidity, phase separation, or evidence of precipitation normally indicates contamination.

X1.11.2 Fuels can encounter conditions in the bulk distribution system that could cause the material to fail a workmanship visual evaluation. Some fuels can contain water, dirt, or rust particles during distribution. Terminals and bulk plants can address these issues with proper operating procedures, for example, by allowing sufficient time for the dirt or rust particles to settle in a tank, by filtration or by other means.

X1.12 Water

X1.12.1 The solubility of hydrocarbons in methanol fuel blends decreases with lowering temperature and increasing water content. Separation of the hydrocarbon from the fuel will adversely affect cold starting and driveability, luminosity, and taste-deterrence. Water may affect the calibration of some types of composition sensors of flexible-fuel vehicles. Water also reduces the energy content of the fuel and thus adversely affects fuel economy and power. Because some degree of water contamination is practically unavoidable in transport and handling, and because the methanol fuel blend is miscible with water, the water content of methanol fuel blends is limited to reduce the potential for problems.

X1.13 Sulfur

X1.13.1 The limit on sulfur content is included to protect against engine wear, deterioration of engine oil, corrosion of exhaust system parts, and exhaust catalyst deactivation.

X2. TEST METHOD FOR LUMINOSITY OF METHANOL FUEL BLENDS (M51–M85) FOR AUTOMOTIVE SPARK-IGNITION ENGINES

X2.1 Scope

X2.1.1 This test method covers a procedure to determine if a methanol fuel blend composition produces a luminous flame throughout the duration of a burn by comparing its luminosity performance under controlled conditions to that of ethanol. The test method in this appendix is included here for information as it represents the current state of development for a luminosity procedure.

X2.1.2 The values stated in SI units are to be regarded as the standard. An exception is footcandles (fc), lumens per square foot (lm/ft^2), that is a hybrid unit and the unit used for the calibration of the optometer.

X2.2 Summary of Test Method

X2.2.1 The sample of methanol fuel blend is measured into a Petri dish resting on a digital scale under a daylight spectrum source (achieved by the use of two daylight spectrum fluorescent bulbs) in a fume hood. The sample is ignited and the output of an optometer and the decreasing output of the scale are recorded on a two pen recorder. A video tape recording of the event is also recommended. A comparison is then made to reagent grade ethanol under the same conditions.

X2.3 Significance and Use

X2.3.1 Potentially low-luminosity (invisible) methanol fires are a major safety consideration. Ensuring that the methanol fuel blend burns with a visible flame over the entire duration of a burn allows visual recognition of a hazardous situation. The test method in this appendix measures a property related to such visual recognition.

X2.4 Apparatus

X2.4.1 *Digital Scale,* having an accuracy of 0.1 g.

X2.4.2 *Borosilicate Petri Dishes,* clean, 100 mm diameter by 20 mm high, one per sample.

X2.4.3 *Disposable Syringes or Clean Pipettes,* 10 mL ± 0.1 mL.

X2.4.4 *Optometer,* with photometric (400 nm to 700 nm) filter.[7]

X2.4.5 *Two-Channel Pen Recorder or similar equipment.*

X2.4.6 *Color Video Camera.*

X2.4.7 *Daylight Spectrum Fluorescent Bulbs.*

X2.5 Reagents and Materials

X2.5.1 *Ethanol*—reagent grade ethyl alcohol, the chemical compound C_2H_5OH.

X2.6 Procedure

X2.6.1 In a laboratory hood equipped with two 30 W daylight spectrum fluorescent bulbs, introduce a 10 mL fuel sample from a clean 10 mL pipette or syringe into a borosilicate Petri dish resting on the pan of a tared digital balance. A standard gray background is recommended if a video recorder is used. Position the optometer sensing head on a 45° angle pointed toward the center of the Petri dish, 41 cm (16 in.) from the vertical center line of the Petri dish (see Fig. X2.1). After zeroing the amplifier with the daylight spectrum fluorescent bulbs on, adjust the amplifier scale to 1.0 fc (10.8 lm/m^2) for burning ethanol in the lighted hood.

X2.6.2 Strike an ordinary wooden match and wave over the test sample, initiating burning at time zero, at which point simultaneously start the video timer graphics and chart feed. Record flame luminosity, measured in footcandles (lm/ft^2 = 10.8 lm/m^2), and weight decrease concurrently on the chart. Termination of the burn is evidenced by the scale's return to zero weight. Obtain the base luminosity value by continuing the trace after the burn. The entire apparatus is shown in Fig. X2.2.

X2.7 Interpretation of Results

X2.7.1 Review the output of the optometer and scale as recorded on the dual-pen recorder (and the video, if recorded) to ensure acceptable luminosity over the entire burn duration. Figs. X2.3-X2.6 illustrate traces that are typical of the results obtained with this technique.

X2.7.2 A numerical result obtained by mathematical comparison of the ethanol standard burn to that of the methanol fuel blend burn, that would ensure a visible flame for the entire duration of the burn is desirable but unavailable at this time.

X2.7.3 The video recording of the burn is important because luminosity by the suggested test method in this appendix does not measure the flame color that is available upon review of the video. Flame color, in addition to luminosity, are important in assessing the visibility of a flame.

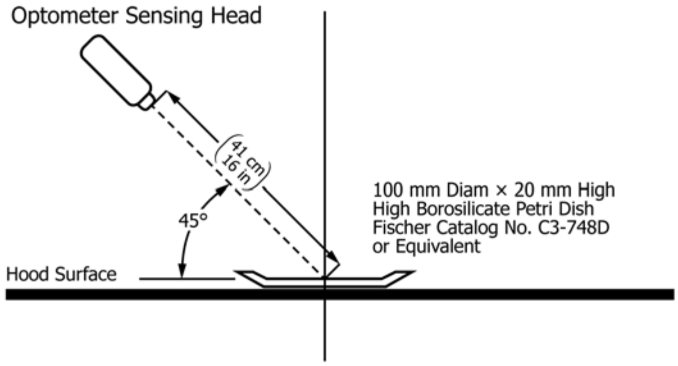

FIG. X2.1 Optometer Sensing Head Position

---

[7] The United Detector Technology Model 40× optometer, or an equivalent, has been found suitable for this purpose.

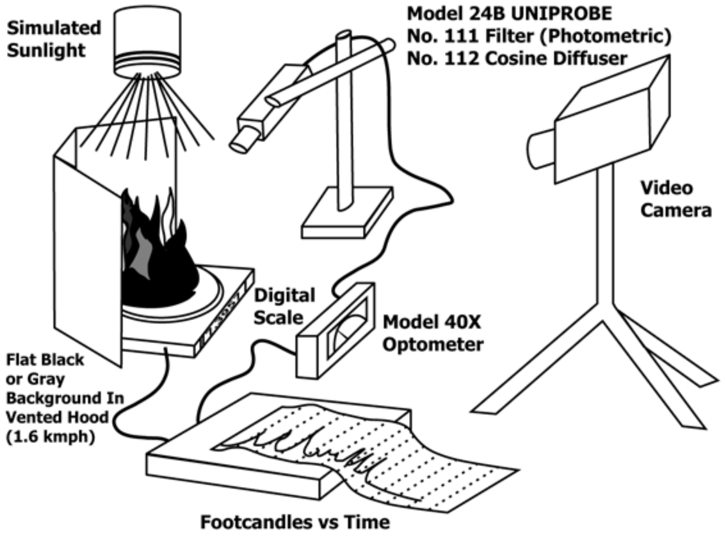

FIG. X2.2 Luminosity Test Apparatus Schematic

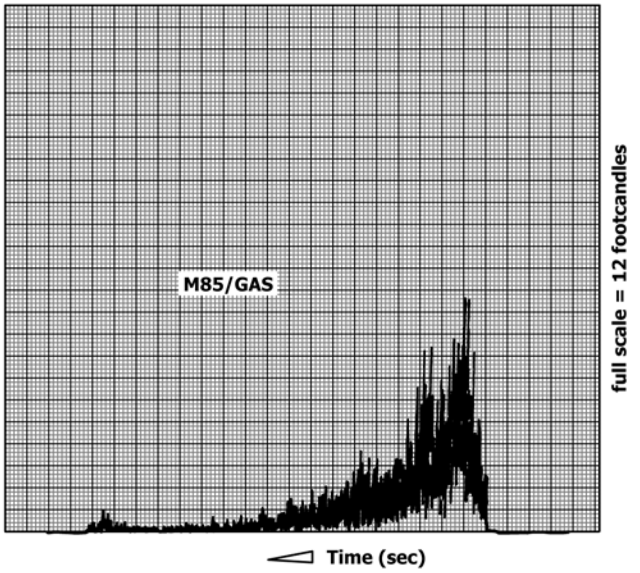

FIG. X2.3 Luminosity Trace of M85, 30 % Aromatic Gasoline

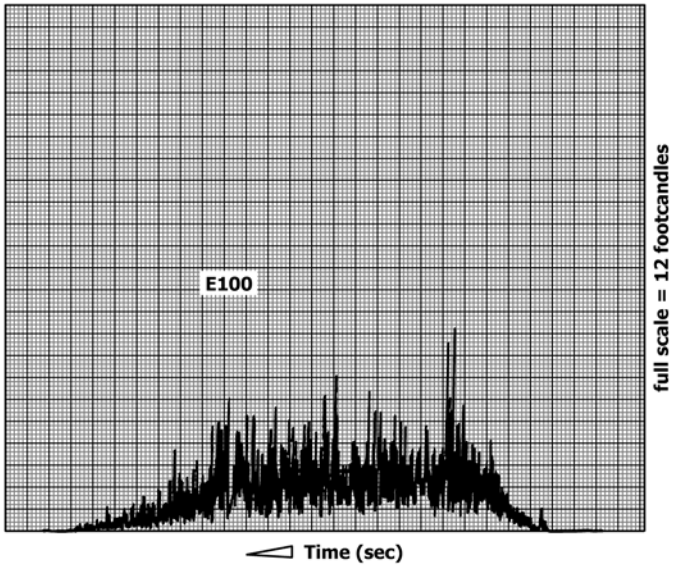

FIG. X2.4 Luminosity Trace of E100

X2.7.4 Correlation with actual vehicle fires has not been established.

X2.8 Precision and Bias

X2.8.1 *Precision*—The precision of the suggested test method in this appendix for measuring the luminosity of methanol fuel blends has not been determined.

X2.8.2 *Bias*—The bias of the suggested test method in this appendix has not been determined.

X2.9 Keywords

X2.9.1 automotive spark-ignition engine fuel; daylight spectrum fluorescent bulb; duration of a burn; ethanol; flame; fuel methanol (M99); illuminance; luminosity; luminous flame; methanol fuel blend; standard daylight spectrum source; video

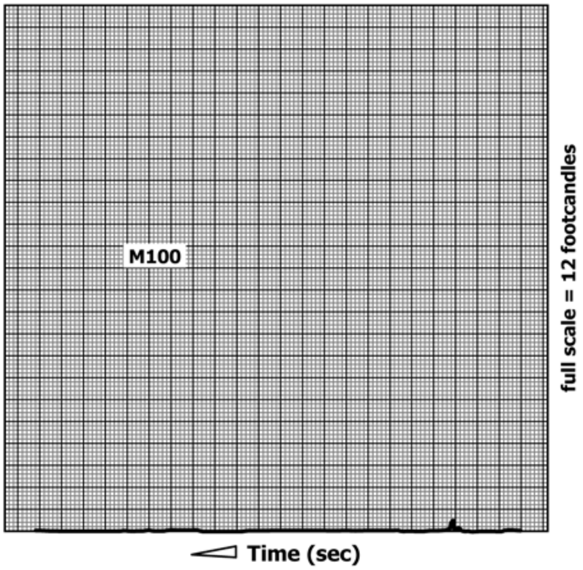

FIG. X2.5 Luminosity Trace of M100

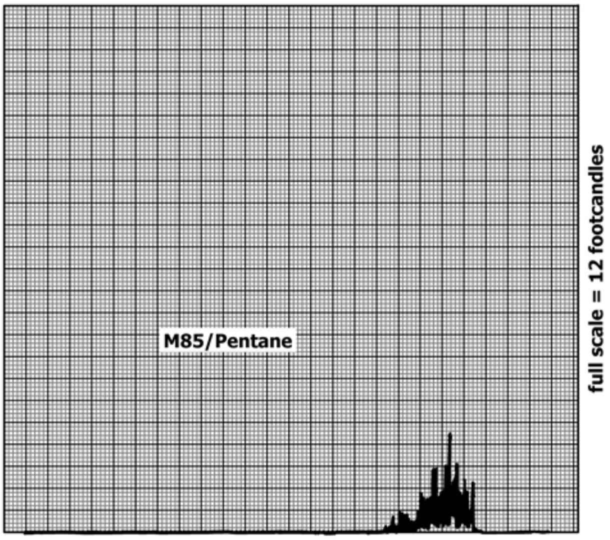

FIG. X2.6 Luminosity Trace of M85/Pentane

SUMMARY OF CHANGES

Subcommittee D02.A0.02 has identified the location of selected changes to this standard since the last issue (D5797 – 15) that may impact the use of this standard. (Approved April 1, 2016.)

(1) Revised scope and title to align them with Specification D5798.
(2) Added several definitions, including one for hydrocarbon blendstock, identified and separated U.S. regulatory requirements.
(3) Moved the discussion of the hydrocarbon blendstock from Section 1, Scope, to Section 5, Methanol Fuel Blends Requirements.
(4) Revised Referenced Documents section to remove several obsolete or unneeded test methods and add Test Method D7920, as well as Terminology D4175, Specification D4806, D5798, Test Method D7328, Test Method D7667, and Test Method D7671.
(5) Revised the hydrocarbon definition in Section 3, Terminology, and inserted a new definition for hydrocarbon blendstock, among other additions.

(6) Added a new Section 4, Ordering Information.

(7) Restructured Section 5, Methanol Fuel Blends Requirements, and added a new Table 2 to clarify hydrocarbon blendstock requirements.

(8) Revised Table 1, Requirements for Fuel Methanol (M51–M85).

(9) Corrected Table A1.1, Seasonal and Geographical Volatility Specifications for Methanol Fuel Blends, and clarified that it uses data unadjusted for altitude.

(10) Replaced Annex A1, Test Method for Determination of Methanol in Fuel Methanol (M70-M85) for Automotive Spark-Ignition Engines with Test Method D7920, Analysis of Product Methanol (M99) and Methanol Blended (M10-M99) in Automotive Spark Ignition Fuels by Gas Chromatography.

(11) Removed Annex 2, Test Method For Determination of Hydrocarbon/Aliphatic Ether Content of Fuel Methanol (M70-M85) for Spark-Ignition Engines.

(12) Remove Annex 3, Test Method for Determination of Inorganic Chloride in Fuel Methanol (M70-M85) for Automotive Spark-Ignition Engines.

(13) Inserted a modified version of Test Method D7328, Determination of Total and Potential Inorganic Sulfate and Total Inorganic Chloride in Fuel Ethanol by Ion Chromatography Using Aqueous Sample Injection, into Section 8, Test Methods.

(14) Established a new section in the Annex on U.S. EPA regulations applicable to D5797 blends, which is aligned with that in Specification D4814.

Subcommittee D02.A0.02 has identified the location of selected changes to this standard since the last issue (D5797 – 13) that may impact the use of this standard. (Approved Oct. 1, 2015.)

(1) Revised Section 3, Terminology.

(2) Revised subsection 6.1 and added new Note 2 and Note 3.

(3) Added new subsection X1.11.2.