



Designation: D 4814 - 92a

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St. Philadelphia, Pa 19103
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An American National Standard

Standard Specification for Automotive Spark-Ignition Engine Fuel¹

This standard is issued under the fixed designation D 4814; 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.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 This specification guides in establishing requirements of automotive fuels for ground vehicles equipped with spark-ignition engines.

1.2 This specification describes various characteristics of automotive fuels for use over a wide range of operating conditions. It provides for a variation of the volatility and water tolerance of automotive fuel in accordance with seasonal climatic changes at the locality where the fuel is used. Although octane rating is one of the more important properties of any automotive spark-ignition engine fuel, this specification does not establish minimum antiknock index requirements. The final responsibility for choosing a suitable level of antiknock index rests with the operator of each individual vehicle. The significance of antiknock index and its variation with seasonal climatic changes and altitude is discussed in Appendix X1. This specification neither necessarily includes all types of fuels that are satisfactory for automotive vehicles, nor necessarily excludes fuels that can perform unsatisfactorily under certain operating conditions or in certain equipment. The significance of this specification is shown in Appendix X1.

1.3 The spark-ignition engine fuels covered in this specification are gasoline and its blends with oxygenates such as alcohols and ethers. This specification does not apply to fuels that contain an oxygenate as the primary component, such as Fuel Methanol (M85). The concentrations and types of oxygenates are not specifically limited in this specification. However, depending on oxygenate type, as oxygenate content increases above some threshold level, the likelihood for vehicle problems also increases. The composition of both unleaded and leaded fuel is limited by economic, legal, and technical consideration, but their properties, including volatility, are defined by this specification. In addition, the composition of unleaded fuel is subject to the rules, regulations, and Clean Air Act waivers of the U.S. Environmental Protection Agency (EPA). With regard to fuel properties, including volatility, this specification can be more or less restrictive than the EPA rules, regulations, and waivers. Refer to Appendix X3 for discussions of EPA rules relating to fuel volatility, lead and phosphorous contents, and use of oxygenates in blends with unleaded gasoline.

1.4 This specification represents a description of automotive fuel as of the date of publication. The specification is

under continuous review, which can result in revisions based on changes in fuel, automotive requirements, or test methods, or a combination thereof. All users of this specification, therefore, should refer to the latest edition.

NOTE 1—If there is any doubt as to the latest edition of Specification D 4814, contact ASTM Headquarters.

1.5 Tests applicable to gasoline are not necessarily applicable to its blends with oxygenates. Refer to the specific test methods for information on their applicability to gasoline-oxygenate blends. The type of fuel under consideration must first be identified, in order to select applicable tests. A method for identifying gasolines that contain alcohols is described in 5.2. A test method for identifying gasolines that contain alcohols or MTBE is Test Method D 4815.

1.6 The test methods in Annexes A1 through A3 are state-of-the-art; however, they may be revised and eventually balloted for publication as separate standards.

1.7 The values stated in SI units are the standard, except when other units are specified by federal regulation. Values given in parentheses are provided for information purposes.

1.8 The following safety hazard caveat pertains only to the test method portions, Annexes A1, A2, and A3 of this specification. *This specification does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this specification 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 86 Test Method for Distillation of Petroleum Products²
- D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test²
- D 323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)²
- D 381 Test Method for Existent Gum in Fuels by Jet Evaporation²
- D 525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)²
- D 1193 Specification for Reagent Water³
- D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)²
- D 2500 Test Method for Cloud Point of Petroleum Oils⁴

¹ This specification is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.A on Gasoline.

Current edition approved May 20, 1992. Published July 1992. Originally published as D 4814 - 88. Last previous edition D 4814 - 92.

² Annual Book of ASTM Standards, Vol 05.01.

³ Annual Book of ASTM Standards, Vol 11.01.

⁴ Annual Book of ASTM Standards, Vol 05.02.

- D 2533 Test Method for Vapor-Liquid Ratio of Spark-Ignition Engine Fuels⁴
- D 2599 Test Method for Lead in Gasoline by X-Ray Spectrometry⁴
- D 2622 Test Method for Sulfur in Petroleum Products by X-Ray Spectrometry⁴
- D 2699 Test Method for Knock Characteristics of Motor Fuels by the Research Method⁵
- D 2700 Test Method for Knock Characteristics of Motor and Aviation Fuels by the Motor Method⁵
- D 2885 Test Method for Research and Motor Method Octane Ratings Using On-Line Analyzers⁵
- D 3116 Test Method for Trace Amounts of Lead in Gasoline⁴
- D 3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry⁴
- D 3229 Test Method for Low Levels of Lead in Gasoline by Wavelength Dispersive X-Ray Spectrometry⁴
- D 3231 Test Method for Phosphorus in Gasoline⁴
- D 3237 Test Method for Lead in Gasoline by Atomic Absorption Spectrometry⁴
- D 3341 Test Method for Lead in Gasoline—Iodine Monochloride Method⁴
- D 4057 Practice for Manual Sampling of Petroleum and Petroleum Products⁶
- D 4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination⁶
- D 4815 Test Method for Determination of C1 to C4 Alcohols and MTBE in Gasoline by Gas Chromatography⁶
- D 4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)⁶
- D 5059 Test Method for Lead in Gasoline by X-Ray Spectroscopy⁶
- D 5190 Test Method for Vapor Pressure of Petroleum Products (Automatic Method)⁶
- D 5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)⁶
- E 1 Specification for ASTM Thermometers⁷

3. Terminology

3.1 Definitions:

3.1.1 *antiknock index*, *n*—the arithmetic average of the Research octane number (RON) and Motor octane number (MON), that is, $(RON + MON)/2$.

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

3.1.3 *gasoline-alcohol blend*, *n*—a fuel consisting primarily of gasoline along with a substantial amount of one or more alcohols.

3.1.4 *gasoline-ether blend*, *n*—a fuel consisting primarily of gasoline along with a substantial amount of one or more ethers.

3.1.5 *gasoline-oxygenate blend*, *n*—a fuel consisting pri-

marily of gasoline along with a substantial amount of one or more oxygenates.

3.1.6 *oxygenate*, *n*—an oxygen-containing, ashless, organic compound, such as an alcohol or ether, which can be used as a fuel or fuel supplement.

3.2 *Applicability*—In order to determine when a fuel contains a substantial amount of an oxygenate, a gasoline-oxygenate blend is defined as a fuel which contains more than 0.35 mass percent oxygen, or more than 0.15 mass percent oxygen if methanol is the only oxygenate. The definitions in this section do not apply to fuels that contain an oxygenate as the primary component; for example, fuel methanol (M85).

NOTE 2—The criteria in 3.2 were selected with consideration given to current oxygenate levels in the marketplace, state labeling practices, and consistency with federal legislation and regulations.

4. Ordering Information

4.1 The purchasing agency shall:

4.1.1 State the antiknock index as agreed upon with the seller,

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

4.1.3 Indicate the lead level required (Table 1), and

4.1.4 State the concentration and types of oxygenates present as agreed upon with the seller.

5. Performance Requirements

5.1 Some requirements and test methods applicable to automotive spark-ignition engine fuel depend on whether the fuel is a gasoline, or a gasoline-oxygenate blend. If it is not known whether a specific fuel is a gasoline-oxygenate blend, fuels containing more than about 0.1 volume % alcohol can be identified using the test described in 5.2. Once the type of fuel is known, the appropriate requirements and test methods can be identified by reference to Table 1 and Section 7.

5.2 A simple laboratory test to determine generally whether oxygenates are present in a fuel is not currently available. However, the alcohol detection test using refraction of light through the water extract of the fuel sample (see Annex A1) should be used to determine if a fuel contains alcohol (methanol through butanols). A detectable change in refractivity of the water extract, as defined in Annex A1, indicates the presence of sufficient alcohol to require special precautions, and references in this specification to oxygenates are applicable. This test may not detect small concentrations of alcohol (less than 0.1 volume %), which, however, can influence the vapor pressure of the fuel. The test does not detect ethers, such as methyl *tert*-butyl ether (MTBE), and does not detect high-molecular weight (beyond butanols) alcohols. The inability to detect ethers would affect the results of the vapor-liquid ratio (*V/L*) Test Method D 2533 because MTBE is miscible with one of the confining fluids (glycerin). Because of these limitations, this alcohol detection test should not be used to decide whether to add oxygenates to a fuel of unknown composition. A gas chromatographic analysis is required to ensure that an oxygenate is not introduced into a fuel already containing oxygenates. A gas chromatographic test method, such as Test Method D 4815,

⁴ Annual Book of ASTM Standards, Vol 05.04.

⁶ Annual Book of ASTM Standards, Vol 05.03.

⁷ Annual Book of ASTM Standards, Vols 05.03 and 14.03.

TABLE 1 Detailed Fuel Requirements^A

Distillation Temperatures, °C(°F), at % Evaporated ^{B,C}						Distillation	Vapor/Liquid Ratio (V/L) ^{B,D}	
Volatility, Class	10 vol %, max	50 vol %		90 vol %, max	End Point, max	Residue, vol %, max	Test Temperature, °C(°F)	V/L, max
		min	max					
A	70(158)	77(170)	121(250)	190(374)	225(437)	2	60(140)	20
B	65(149)	77(170)	118(245)	190(374)	225(437)	2	56(133)	20
C	60(140)	77(170)	116(240)	185(365)	225(437)	2	51(124)	20
D	55(131)	77(170)	113(235)	185(365)	225(437)	2	47(116)	20
E	50(122)	77(170)	110(230)	185(365)	225(437)	2	41(105)	20

Volatility, Class	Vapor Pressure, ^{E,F} max kPa (psi)	Lead Content, max, g/L (g/U.S. gal) ^G		Copper Strip Corrosion, max	Existent Gum, max, mg/100 mL	Sulfur, max, mass %		Oxidation Stability, Minimum, Minutes	Water Tolerance
		Unleaded	Leaded			Unleaded	Leaded		
A	62(9.0)	0.013(0.05)	1.1(4.2)	No. 1	5	0.10	0.15	240	H
B	69(10.0)	0.013(0.05)	1.1(4.2)	No. 1	5	0.10	0.15	240	H
C	79(11.5)	0.013(0.05)	1.1(4.2)	No. 1	5	0.10	0.15	240	H
D	93(13.5)	0.013(0.05)	1.1(4.2)	No. 1	5	0.10	0.15	240	H
E	103(15.0)	0.013(0.05)	1.1(4.2)	No. 1	5	0.10	0.15	240	H

^A See X1.4 for information on Antiknock Index.

^B At 101.3 kPa pressure (760 mm Hg).

^C If Federal legislation or regulatory action restricts vapor pressure to a level lower than the volatility classes specified in Table 2 for a given time and place, the distillation temperature limits shall be consistent with the corresponding vapor pressure in Table 1. If the vapor pressure limit is between the two classes, the distillation temperature limits of either class are acceptable.

^D The mercury confining fluid procedure of Test Method D 2533 shall be used for gasoline-oxygenate blends. Either glycerin or mercury confining fluid may be used for gasoline. Subcommittee D02.08 is investigating a possible bias of the mercury procedure and the suitability of using glycerin for gasoline-ether blends. The procedure for estimating temperature-V/L (see Appendix X2) may only be used for gasoline.

^E The dry methods described in Test Methods D 4953, D 5190, or D 5191 shall be used for gasoline-alcohol blends.

^F See Table X3.1 in Appendix X3 for U.S. EPA applicable vapor pressure standards and approved state maximum vapor pressure limits for May 1 through September 15.

^G See Appendix X3 for U.S. EPA maximum limits for lead and phosphorus contents in unleaded gasoline (X3.2.1) and maximum average lead limits for leaded gasoline (X3.2.2).

^H Water tolerance limits in terms of maximum temperature for phase separation are given in Table 3 (consult Annex A3).

can be used to detect ethers as well as determine the presence of alcohols.

5.3 Volatility of fuels is varied for seasonal climatic changes by providing for five volatility classes of fuel, which conform to the requirements prescribed in Table 1.

5.3.1 The seasonal and geographical distribution of the five classes is shown in Table 2.

5.3.2 The Reid vapor pressure test method (Test Method D 323) is applicable to gasoline and gasoline-ether blends, but not to gasoline-alcohol blends (see X1.6). The dry vapor pressure methods in Test Methods D 4953, D 5190, or D 5191 shall be used for gasoline-alcohol blends. These three dry methods may also be used for determining vapor pressure of gasoline and gasoline-ether blends.

5.3.3 Test Method D 2533 contains procedures for measuring temperature-V/L of both gasoline and gasoline-oxygenate blends. For gasoline-oxygenate blends, the procedure requires that mercury be used as the confining fluid in place of glycerin. Either confining fluid may be used for gasoline. Subcommittee D02.08 is investigating a possible bias of the mercury procedure and the suitability of using glycerin for gasoline-ether blends. An alternative method for measuring temperature-V/L of 20 for gasoline-oxygenate blends, as well as gasoline, using a bomb method is shown in Annex A2. This test method is under development by Subcommittee D02.08. In case of dispute, Test Method D 2533 is the referee method. The method for estimating (see Appendix X2) temperature-V/L is only applicable for gasoline.

5.4 Antiknock index (AKI) is very important to engine performance. The matching of engine octane requirement to fuel octane level (AKI) is critical to the durability and

performance of engines; this cannot be accomplished with a single specified minimum level of antiknock index. Appendix X1 includes a discussion of antiknock indexes of fuels currently marketed and relates these levels to the octane needs of broad groups of engines and vehicles. Also discussed is the effect of altitude and weather on vehicle antiknock requirements.

5.5 Additional fuel requirements are listed in Table 1.

5.6 The properties of gasoline-oxygenate blends can differ considerably from those of gasoline. Consequently, additional requirements are needed for gasoline-oxygenate blends. These requirements involve evaluation of compatibility with plastic and elastomeric materials in fuel systems, corrosion of metals, and especially in the case of gasoline-alcohol blends, water tolerance. Requirements for metal corrosion (other than copper) and material compatibility are not given because test methods and appropriate limits are still under development. When these have been developed they will be included in this specification. Water tolerance is specified in Table 3.

5.7 Depending on oxygenate type and concentration in the blend, vehicle driveability with gasoline-oxygenate blends can differ significantly from that with gasolines having similar volatility characteristics.

5.8 Water Tolerance:

5.8.1 The term water tolerance is used to indicate the ability of a gasoline-oxygenate blend to dissolve water without phase separation. This may not be a problem with gasoline-ether blends, but it is of primary concern for alcohol-containing blends, as blends of gasoline with low-molecular weight alcohols generally will dissolve about 0.1 to 0.7 mass % of water under normal conditions, depending on the nature and amount of the alcohol(s) used, the specific



D 4814

TABLE 2 Schedule of Seasonal and Geographical Volatility Classes

This schedule, subject to agreement between purchaser and seller, denotes the volatility properties of the fuel at the time and place of shipment. Shipments intended for future use may anticipate this schedule.

Where alternative classes are permitted, either class is acceptable; the option shall be exercised by the seller.

State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alabama	D	D	D/C	C	C	C	C/B	B	B/C	C	C/D	D
Alaska	E	E	E	E	E/D	D	D	D	D/E	E	E	E
Arizona:												
N 34° Latitude and												
E 111° Longitude	D	D	D/C	C/B	B/A	A	A	A/B	B	B/C	C/D	D
Remainder of State	D	D/C	C/B	B	B/A	A	A	A	A	A/B	B/C	C/D
Arkansas	E/D	D	D/C	C	C	C/B	B	B	B/C	C/D	D	D/E
California:												
North Coast	E/D	D	D	D/C	C	C/B	B	B	B	B/C	C/D	D/E
South Coast	D	D	D/C	C	C/B	B	B	B	B	B/C	C/D	D
Southeast	D	D/C	C/B	B	B/A	A	A	A	A	A/B	B/C	C/D
Interior	E/D	D	D	D/C	C/B	B	B	B	B	B/C	C/D	D/E
Colorado	E	E/D	D/C	C	C/B	B	B/A	A/B	B	B/C	C/D	D/E
Connecticut	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
Delaware	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
District of Columbia	E	E/D	D	D/C	C	C	C	C	C	C/D	D/E	E
Florida	D	D	D/C	C	C	C	C	C	C	C	C/D	D
Georgia	D	D	D/C	C	C	C	C/B	B	B/C	C	C/D	D
Hawaii	C	C	C	C	C	C	C	C	C	C	C	C
Idaho:												
N 46° Latitude	E	E	E/D	D	D/C	C/B	B	B	B/C	C/D	D/E	E
S 46° Latitude	E	E/D	D	D/C	C/B	B	B	B	B	B/C	C/D	D/E
Illinois:												
N 40° Latitude	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
S 40° Latitude	E	E	E/D	D/C	C	C	C/B	B/C	C	C/D	D	D/E
Indiana	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
Iowa	E	E	E/D	D/C	C	C/B	B/C	C	C	C/D	D/E	E
Kansas	E	E/D	D/C	C	C/B	B	B	B	B	B/C	C/D	D/E
Kentucky	E	E/D	D	D/C	C	C	C	C	C	C/D	D/E	E
Louisiana	E	D	D/C	C	C	C	C/B	B	B/C	C	C/D	D
Maine	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
Maryland	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
Massachusetts	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
Michigan	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
Minnesota	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
Mississippi	D	D	D/C	C	C	C	C/B	B	B/C	C	C/D	D
Missouri	E	E/D	D	D/C	C	C/B	B	B	B/C	C/D	D	D/E
Montana	E	E	E/D	D/C	C/B	B	B	B	B/C	C/D	D/E	E
Nebraska	E	E	E/D	D/C	C/B	B	B	B	B	B/C	C/D	D/E
Nevada:												
N 38° Latitude	E	E/D	D	D/C	C/B	B	B	B	B	B/C	C/D	D/E
S 38° Latitude	D	D/C	C/B	B	B/A	A	A	A	A	A/B	B/C	C/D
New Hampshire	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
New Jersey	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
New Mexico:												
N 34° Latitude	E/D	D	D/C	C/B	B/A	A	A	A/B	B	B/C	C/D	D
S 34° Latitude	D	D/C	C/B	B	B/A	A	A	A	A/B	B/C	C/D	D
New York	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
North Carolina	E/D	D	D	D/C	C	C	C/B	B	B/C	C/D	D	D/E
North Dakota	E	E	E/D	D	D/C	C/B	B	B	B/C	C/D	D/E	E
Ohio	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
Oklahoma	E/D	D	D/C	C	C/B	B	B	B	B	B/C	C/D	D/E
Oregon:												
E 122° Longitude	E	E/D	D	D	D/C	C/B	B	B	B/C	C/D	D	D/E
W 122° Longitude	E	E/D	D	D	D/C	C	C	C	C	C/D	D/E	E
Pennsylvania	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
Rhode Island	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
South Carolina	D	D	D	D/C	C	C	C/B	B	B/C	C/D	D	D
South Dakota	E	E	E/D	D/C	C/B	B	B	B	B	B/C	C/D	D/E
Tennessee	E/D	D	D	D/C	C	C	C/B	B	B/C	C/D	D	D/E
Texas:												
E 99° Longitude	D	D	D/C	C	C	C/B	B	B	B	B/C	C/D	D
W 99° Longitude	D	D/C	C/B	B	B/A	A	A	A	A/B	B/C	C/D	D
Utah	E	E/D	D	D/C	C/B	B	B/A	A/B	B	B/C	C/D	D/E
Vermont	E	E	E/D	D	D/C	C	C	C	C/D	D	D/E	E
Virginia	E	E/D	D	D/C	C	C	C	C	C	C/D	D/E	E
Washington:												
E 122° Longitude	E	E	E/D	D	D/C	C/B	B	B	B/C	C/D	D/E	E
W 122° Longitude	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
West Virginia	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
Wisconsin	E	E	E/D	D	D/C	C	C	C	C	C/D	D/E	E
Wyoming	E	E	E/D	D/C	C/B	B	B	B	B	B/C	C/D	D/E

^a Details of State Climatological Division by county as indicated:

California, North Coast—Alameda, Contra Costa, Del Norte, Humboldt, 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 the Los Angeles County Aqueduct), Kings, Madera, Mariposa, Merced, 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 Bernardino, 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).

TABLE 3 Maximum Temperature for Phase Separation, °C^a

Temperature Conversion °F = (°C × 1.8) + 32°												
State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Alabama	-4	-3	0	5	10	10	10	10	10	6	0	-4
^b Alaska:												
Southern Region	-27	-26	-23	-11	1	7	9	7	1	-9	-19	-23
South Mainland	-41	-39	-31	-14	-1	7	9	5	-2	-18	-32	-41
N of 62° Latitude												
Arizona:												
N of 34° Latitude	-11	-7	-7	-2	2	6	10	10	6	1	-6	-9
S of 34° Latitude	-2	-1	2	7	10	10	10	10	10	9	2	-1
Arkansas	-9	-6	-2	6	10	10	10	10	10	4	-2	-6
^c California												
North Coast	-2	0	1	4	5	8	9	9	8	6	2	-2
South Coast	-2	-1	2	4	7	9	10	10	9	6	1	-2
Southeast	-7	-3	-1	3	8	10	10	10	9	4	-3	-6
Interior	-4	-3	-3	-1	3	9	10	10	10	6	0	-2
Colorado:												
E of 105° Longitude	-14	-12	-9	-3	4	10	10	10	7	1	-8	-11
W of 105° Longitude	-24	-20	-12	-6	-1	4	8	6	1	-6	-14	-21
Connecticut	-14	-13	-8	-1	5	10	10	10	7	1	-4	-12
Delaware	-9	-8	-3	0	8	10	10	10	10	4	-1	-8
District Columbia	-8	-7	-3	3	9	10	10	10	10	5	0	-7
Florida:												
N of 29° Latitude	-1	1	4	9	10	10	10	10	10	9	3	-1
S of 29° Latitude	4	7	8	10	10	10	10	10	10	10	9	5
Georgia	-5	-2	1	6	10	10	10	10	10	6	0	-3
Hawaii	10	10	10	10	10	10	10	10	10	10	10	10
Idaho	-17	-16	-11	-3	-5	4	10	9	3	-2	-11	-15
Illinois:												
N of 40° Latitude	-18	-16	-9	-1	4	10	10	10	7	1	-7	-16
S of 40° Latitude	-15	-12	-7	1	7	10	10	10	9	3	-6	-13
Indiana	-16	-13	-7	-1	4	10	10	10	7	1	-6	-14
Iowa	-23	-19	-13	-3	4	10	10	10	6	0	-12	-20
Kansas	-17	-12	-9	-3	5	10	10	10	7	0	-8	-13
Kentucky	-12	-9	-4	1	8	10	10	10	9	3	-4	-11
Louisiana	-3	0	3	8	10	10	10	10	10	7	2	-1
Maine	-24	-22	-16	-4	1	7	10	8	3	-2	-8	-20
Maryland	-9	-8	-3	3	9	10	10	10	10	4	-2	-8
Massachusetts	-15	-14	-7	-1	4	10	10	10	6	0	-4	-13
^d Michigan:												
Lower Michigan	-18	-17	-12	-3	1	7	10	9	5	0	-6	-14
Upper Michigan	-21	-20	-15	-6	-1	6	9	9	4	-1	-9	-18
Minnesota	-31	-28	-20	-7	0	6	10	8	1	-3	-16	-28
Mississippi	-3	-1	2	7	10	10	10	10	10	7	1	-3
Missouri	-14	-11	-6	1	8	10	10	10	10	3	-5	-12
Montana	-28	-24	-19	-6	1	5	9	8	1	-5	-17	-23
Nebraska	-19	-14	-11	-3	4	9	10	10	5	-2	-10	-16
Nevada:												
N of 38° Latitude	-18	-13	-8	-3	1	5	9	7	2	-3	-11	-14
S of 38° Latitude	-9	-5	-1	1	9	10	10	10	10	4	-3	-6
New Hampshire	-18	-17	-9	-2	3	9	10	9	3	-1	-6	-16
New Jersey	-10	-9	-4	2	7	10	10	10	10	4	-1	-8
New Mexico:												
N of 34° Latitude	-14	-11	-7	-2	1	7	10	10	7	1	-8	-12
S of 34° Latitude	-7	-5	-1	6	10	10	10	10	10	7	-2	-5
New York:												
N of 42° Latitude	-21	-20	-13	-3	2	9	10	10	4	-1	-6	-18
S of 42° Latitude	-13	-13	-7	1	6	10	10	10	8	2	-3	-12
North Carolina	-9	-7	-3	1	7	10	10	10	8	1	-5	-8
North Dakota	-29	-27	-11	-6	1	8	10	10	3	-2	-17	-24
Ohio	-14	-13	-8	-2	6	10	10	10	7	1	-5	-13
Oklahoma	-12	-6	-5	1	7	10	10	10	10	4	-4	-9
Oregon:												
E of 122° Longitude	-17	-12	-6	-3	0	4	6	6	2	-3	-8	-12
W of 122° Longitude	-5	-3	-1	2	5	8	10	10	7	2	-3	-3
Pennsylvania:												
N of 41° Latitude	-17	-19	-13	-4	1	6	9	8	2	-1	-6	-16
S of 41° Latitude	-13	-14	-9	-1	5	10	10	10	7	2	-4	-12
Rhode Island	-11	-11	-5	1	6	10	10	10	8	3	-2	-10
South Carolina	-3	-2	0	6	10	10	10	10	10	7	1	-3
South Dakota	-24	-21	-16	-4	3	10	10	10	4	-2	-12	-21
Tennessee	-9	-7	-3	2	9	10	10	10	10	2	-3	-8

TABLE 3 Continued

Temperature Conversion °F = (°C × 1.8) + 32°												
State	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Texas:												
N of 31° Latitude	-11	-8	-4	2	8	10	10	10	10	5	-3	-7
S of 31° Latitude	-1	1	4	10	10	10	10	10	10	10	3	1
Utah	-15	-11	-7	-2	2	8	10	10	7	2	-11	-12
Vermont	-20	-21	-12	-2	2	9	10	10	5	0	-6	-17
Virginia	-8	-7	-3	3	9	10	10	10	10	4	-2	-7
Washington:												
E of 122° Longitude	-13	-6	-3	1	4	7	10	10	7	1	-5	-7
W of 122° Longitude	-6	-2	-2	1	4	7	9	9	6	2	-2	-2
West Virginia	-13	-12	-7	-2	4	9	10	10	5	-2	-7	-12
Wisconsin	-25	-21	-15	-3	3	8	10	10	5	-1	-11	-21
Wyoming	-23	-17	-14	-6	0	5	10	10	3	-2	-13	-16

^A A maximum phase separation temperature of 10°C (50°F) is specified, even if the 6-h 10th percentile minimum temperature for the area and month can be higher.

^B The designated areas of Alaska are divided as follows:

Southern Region—The Aleutians, Kodiak Island, the coastal strip East of Longitude 141°, and the Alaskan Peninsula South of Latitude 52°.

South Mainland—The portion of Alaska South of Latitude 62°, except the Southern Region.

North of Latitude 62°—The specification test temperature must be agreed between the vendor and purchaser having regard to equipment design, expected weather conditions, and other relevant factors.

^C The designated areas of California are divided by county as follows:

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

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

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

Southeast—Imperial, Riverside, San Bernardino, Los Angeles (that portion lying 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).

^D The designated areas of Michigan are divided as follows:

Lower Michigan—That portion of the state lying East of Lake Michigan.

Upper Michigan—That portion of the state lying North of Wisconsin and of Lake Michigan.

hydrocarbons present, and the temperature of the blend. When blends are exposed to a greater amount of water than they can dissolve, they separate into an alcohol-rich aqueous phase, the volume of which can be significantly greater than that of the additional water, and an alcohol-poor hydrocarbon phase. As the aqueous phase can be highly corrosive to many metals and the engine cannot operate on it, such separation is very undesirable. Blends containing low-molecular weight alcohols are generally hygroscopic and can eventually absorb enough moisture from ambient air to cause separation. The problem of phase separation can usually be avoided if the fuels are sufficiently water-free initially and care is taken during distribution to prevent contact with water. To help ensure this, gasoline-oxygenate blends shall be tested at the lowest temperatures to which they can be subjected, dependent on the time and place of intended use, as indicated in Table 3. The values in Table 3 are the 10th percentile 6-h minimum temperatures, with each reading specifically defined as the highest temperature of the six coldest consecutive hourly temperature readings of a 24-h day. For April through September (and occasionally October, and year-round for Hawaii), Table 3 specifies a minimum phase separation temperature of 10°C (50°F), even though the 10th percentile 6-h minimum temperature can be higher. Use of this temperature limit also reduces the risk of separation of the fuel in storage tanks where temperatures may be lower than ambient.

NOTE 3—The values in Table 3 are taken from the U.S. Army Belvoir Research Development and Engineering Center's Report No. 316, entitled "A Predictive Study for Defining Limiting Temperatures and Their Application in Petroleum Product Specifications." This can be obtained as Publication AD756-420 from the National Technical

Information Service, Springfield, VA 22151.

5.8.2 The test procedure (see Annex A3) consists of cooling the fuel under specified conditions to the appropriate temperature listed in Table 3. It is important to note that when cooling to a low temperature some gasolines and many gasoline-oxygenate blends, especially those containing ethers, can take on a hazy appearance. This haze must be carefully distinguished from the test criterion described in Annex A3 of separation into two distinct phases with a more or less distinct common boundary, and must not be considered grounds for rejection of the fuel. This test also must not be confused with that described in Section 6, which is conducted at 21°C (70°F) or above, and for which the appearance of haze is proper grounds for rejection.

6. Workmanship

6.1 The finished fuel shall be visually free of undissolved water, sediment, and suspended matter; it shall be clear and bright at the ambient temperature or 21°C (70°F), whichever is higher.

6.2 Fuel to be used in this test shall not be cooled below about 15°C (59°F) or its temperature at the time the sample was taken, whichever is lower, as cooling of gasoline-oxygenate blends can produce changes in appearance that are not reversed on rewarming.

7. Test Methods

7.1 The requirements enumerated in this specification shall be determined in accordance with the following methods:

7.1.1 *Distillation*—Test Method D 86.

D 4814

7.1.2 Vapor-Liquid Ratio—Test Method D 2533 has procedures for determining vapor-liquid (V/L) ratios for both gasoline and gasoline-oxygenate blends. Because some oxygenates are miscible with the glycerin used in one procedure, another procedure using mercury as the confining fluid is provided for gasoline-oxygenate blends. Either procedure may be used to determine V/L for gasoline, but a possible bias between the two procedures is under investigation by Subcommittee D02.08. An investigation is also underway by Subcommittee D02.08 to determine the suitability of using the glycerin procedure for gasoline-ether blends.

7.1.2.1 Annex A2 describes a bomb procedure for determining the temperature at a V/L of 20. This test method is under development by Subcommittee D02.08.

7.1.3 Vapor Pressure—Test Method D 323 is applicable to gasoline and gasoline-ether blends, but not to gasoline-alcohol blends. For gasoline-alcohol blends use the dry Test Methods D 4953, D 5190, or D 5191. These three dry methods may also be used for determining the vapor pressure of gasoline and gasoline-ether blends.

7.1.4 Corrosion, for Copper, Test Method D 130, 3 h at 50°C (122°F).

7.1.5 Existent Gum—Test Method D 381, air jet apparatus.

7.1.6 Sulfur—Test Methods D 1266, D 2622, or D 3120. With Test Method D 3120, fuels with sulfur content greater than 100 ppm (0.0100 mass %) must be diluted with isooctane. The dilution of the sample may result in a loss of precision. Test Method D 3120 cannot be used when the

lead concentration is greater than 0.4 g/L (1.4 g/U.S. gal).

7.1.7 Lead—Test Methods D 2599, D 3341, or D 5059 (Test Methods A or B). For lead levels below 0.03 g/L (0.1 g/U.S. gal) use Test Methods D 3116, D 3229, D 3237, or D 5059 (Test Method C).

7.1.8 Oxidation Stability—Test Method D 525.

7.1.9 Alcohol Detection—Test Method D 4815 or see Annex A1.

7.1.10 Water Tolerance—See Annex A3 for a test method.

8. Precision and Bias

8.1 The precision of each required test method with gasoline is included in the standard applicable to each method. In many cases, the precision applicable to gasoline-oxygenate blends has not been established yet.

9. Keywords

9.1 automotive spark-ignition engine fuel; automotive gasoline; automotive fuel; gasoline; gasoline-alcohol blend; gasoline-ethanol blend; gasoline-oxygenate blend; oxygenate; fuel; unleaded fuel; leaded fuel; alcohol; alcohol detection; ethanol; methanol; ether; MTBE; volatility; vapor pressure; distillation; vapor-liquid ratio; $T_{V/L=20}$; vapor lock; driveability; antiknock index; octane number; octane requirement; lead; corrosion; copper strip corrosion; existent gum; sulfur; oxidation stability; induction period; water tolerance; phase separation; EPA regulations; phosphorus

ANNEXES

(Mandatory Information)

A1. TEST METHOD FOR DETECTION OF ALCOHOL IN SPARK-IGNITION ENGINE FUEL (REFRACTION METHOD)

A1.1 Scope

A1.1.1 This test method pertains to the determination of the presence of alcohols (methanol through butanol) in automotive spark-ignition engine fuels. The test results are used to determine which limits and analytical tests of Specification D 4814 are applicable to the fuel tested.

A1.1.2 This test method is state-of-the-art; however, it may be revised and eventually balloted for publication as a separate standard.

A1.2 Summary of Test Method

A1.2.1 A sample of the fuel is shaken, using a standardized technique, with distilled water at room temperature. The mixture is allowed to settle into two phases, and a refractometer is used to obtain a reading of the lower aqueous phase. A minimum specified increase in the refractometer reading over that of distilled water indicates that an alcohol is present.

A1.3 Significance and Use

A1.3 Based on the results of a round-robin evaluation, a

scale reading of 0.5 or greater was selected to indicate that alcohol is present in a fuel sample. A reading of 0.5 on average is equivalent to 0.05 vol % ethanol, 0.11 vol % methanol, or 50/50 mixture of methanol and *tert*-butyl alcohol (TBA), or 0.13 vol % TBA.

A1.3.2 This test method should not be used for deciding whether to add an oxygenate to a fuel of unknown composition. This method does not determine the type of alcohol and does not detect ethers such as MTBE. A gas chromatographic method, such as Test Method D 4815, must be used to determine the types and concentrations of oxygenates to avoid adding an oxygenate to a blend already containing some type of oxygenate, and to ensure compliance with EPA rules and waivers.

A1.4 Apparatus

A1.4.1 *Graduated Glass Cylinder*, glass-stoppered, 100-mL, with 1-mL graduations.

A1.4.2 *Pipet*, 2-mL.

A1.4.3 *Pipet Filler or Bulb*.

A1.4.4 *Refractometer*,⁸ temperature compensated, hand held, 0 to 10° Brix (1.3330–1.3479).

A1.5 Reagents

A1.5.1 *Purity of Reagents*—Reagent-grade chemicals will 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, where such specifications are available.⁹ Other grades may be used, provided it is first ascertained that the reagent is of sufficient purity to permit its use without lessening the accuracy of the determination.

A1.5.2 *Purity of Water*—Unless otherwise indicated, reference to water shall be understood to mean distilled water or water of equivalent purity. See Specification D 1193, Type IV.

A1.5.3 Acetone

NOTE A1.1: *Acetone*—**Warning**—Extremely flammable. Irritating to skin, eyes, and mucous membranes.

A1.5.4 *n-Heptane* conforming to material used in Test Methods D 381, D 2699, and D 2700, or petroleum spirit 60/80 conforming to IP specification or equivalent. Commercial grade quality is adequate for these solvents.

NOTE A1.2: *n-Heptane*—**Warning**—Flammable. Harmful if inhaled. Skin irritant on repeated contact. Aspiration hazard.

NOTE A1.3: *Petroleum Spirit (Mineral Spirits)*—**Warning**—Combustible. Skin irritant on repeated contact. Aspiration hazard.

A1.6 Preparation of Apparatus

A1.6.1 Clean the graduated cylinder and pipet thoroughly before carrying out this test. The recommended cleaning procedure is as follows:

A1.6.1.1 Remove traces of oil from the cylinder, stopper, and pipet by flushing with hot tap water, brushing if necessary. Alternatively, remove all traces of oil from the glassware by using either *n*-heptane or the IP solvent 60/80. Rinse with acetone followed by tap water.

A1.6.1.2 Immerse the cylinder, stopper, and pipet in warm detergent solution, follow with tap water, distilled water, and acetone rinses. After the acetone rinse, thoroughly drain and dry the cylinder, stopper, and pipet.

A1.6.2 Open the cover plate of the refractometer and using a soft cloth, or soft tissue paper moistened with water, wipe the prism and cover plate. Dry both surfaces with a soft, dry cloth or tissue. Then close the cover plate. Fill a clean pipet with distilled water using the pipet filler. Tilt the refractometer with the eyepiece up. Place the pipet tip at the top of the cover plate between the hinges and discharge a few drops of distilled water until the prism is at least half covered with liquid. Immediately point the instrument toward a window or other source of light so that the light enters from above. Look through the eyepiece and take the reading at the point where the dividing line between light and dark crosses

the scale. This should provide a reading of zero. If not, the water is contaminated or the instrument is out of calibration and shall not be used.

NOTE A1.4—The dividing line between the light and dark areas of the scale can sometimes be difficult to see. The best way to see it is to hold the refractometer slightly away from the eye. When using a lamp as the light source, the refractometer and observer's head should be positioned 0.3 m (1 ft) away from the lamp so that the light enters from above at 45°. The refractometer and observer's head shall be moved together until optimum contrast on the scale is obtained.

A1.7 Procedure

A1.7.1 Measure 100 mL of the fuel to be tested, at room temperature, into the 100-mL graduated cylinder.

A1.7.2 Add 2 mL of distilled water using the pipet and pipet filler and stopper the cylinder.

A1.7.3 Invert the cylinder, holding the stopper with a finger, and allow the water to flow into the sample. Keeping the cylinder in a horizontal attitude, shake it vigorously for exactly 2 min, two to three strokes per second, using 125 to 250 mm (5 to 10 in.) strokes.

A1.7.4 Immediately place the cylinder in a vertical position on a vibration-free surface and allow the contents to settle undisturbed for 5 min.

A1.7.5 Open the cover plate of the refractometer and using a soft cloth, or soft tissue paper moistened with water, wipe the prism and cover plate. Dry both surfaces with a soft, dry cloth or tissue. Then close the cover plate.

A1.7.6 Air dry the pipet and install the pipet filler. Remove the stopper from the graduated cylinder, tilt the cylinder, and insert the pipet with the tip in the water phase. Squeeze the pipet filler and discharge air through the pipet to purge any fuel that has entered the pipet tip. Draw up into the pipet about one-half of the water phase in the bottom of the cylinder. Try to avoid drawing in any emulsion.

NOTE A1.5—If the water is totally absorbed into the fuel phase, this indicates that the sample contains a high concentration (greater than 25 volume %) of ethanol or heavier alcohol.

A1.7.7 Remove the pipet from the graduated cylinder, dry the outside of the pipet with tissue to remove any fuel on the surface, and then discharge a few drops of water phase to purge any fuel in the tip. Tilt the refractometer with the eyepiece up. Without lifting the cover plate, place the pipet tip at the top of the cover plate between the hinges and discharge enough of the water phase to cover at least half of the prism.

A1.7.8 Immediately point the instrument toward a window or other source of light so the light enters the prism from above. Look through the eyepiece and take the reading at the point where the dividing line between light and dark crosses the scale.

NOTE A1.6—Take the reading within 10 s of discharging the water phase onto the refractometer prism. The reading can change with time as constituents evaporate or the sample otherwise changes in composition.

A1.7.9 Record the scale reading.

A1.8 Report

A1.8.1 The report shall include the refractometer scale reading. If the reading is off scale, report 10 +° Brix. If the value is equal to or greater than 0.5° Brix, the sample is to be

⁸ The Misco Products Tester Model 10441 Automatic Temperature Compensated Hand Refractometer has been found suitable. Also an equivalent may be used.

⁹ "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and "United States Pharmacopeia."