



## **Standard Specification for Automotive Spark-Ignition Engine Fuel<sup>1</sup>**

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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of 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. For the period May 1 through September 15, the maximum vapor pressure limits issued by the U.S. Environmental Protection Agency (EPA) are specified for each geographical area except Alaska and Hawaii. Variation of antiknock index 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 each of the properties 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, deposit control additive certification, and use of oxygenates in blends with unleaded gasoline. Contact EPA for the latest versions of the rules and additional requirements.

1.4 This specification does not address the emission characteristics of reformulated spark-ignition engine fuel. Reformulated spark-ignition engine fuel is required in some areas to lower emissions from automotive vehicles, and its characteristics are described in the research report on reformulated spark-ignition engine fuel.<sup>2</sup> However, in addition to the legal requirements found in this research report, reformulated spark-ignition engine fuel should meet the performance requirements found in this specification.

1.5 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 International Headquarters.

1.6 Tests applicable to gasoline are not necessarily applicable to its blends with oxygenates. Consequently, the type of fuel under consideration must first be identified in order to select applicable tests. Test Method D 4815 provides a procedure for determining oxygenate concentration in mass percent. Test Method D 4815 also includes procedures for calculating mass oxygen content and oxygenate concentration in volume percent. Appendix X4 provides a procedure for calculating the mass oxygen content of a fuel using measured oxygenate type, oxygenate concentration in volume percent, and measured density or relative density of the fuel.

1.7 The following applies to all specified limits in this standard: For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded “to the nearest unit” in the right-most significant digit used in expressing the specification limit, in accordance with

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.A0 on Gasoline and Oxygenated Fuels.

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<sup>2</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1347.



**TABLE 1 Vapor Pressure and Distillation Class Requirements**

Vapor Pressure/ Distillation Class	Vapor Pressure, <sup>A</sup> max, kPa(psi)	Distillation Temperatures, °C (°F), at % Evaporated. max <sup>B</sup>				Distillation Residue, volume % , max	Driveability Index, <sup>C</sup> max, °C (°F) Derived <sup>D,E</sup>	
		10 volume %, max	50 volume %		90 volume %, max			
			min	max				
AA	54(7.8)	70.(158.)	77.(170.)	121.(250.)	190.(374.)	225.(437.)	2.	597. (1250.)
A	62(9.0)	70.(158.)	77.(170.)	121.(250.)	190.(374.)	225.(437.)	2.	597. (1250.)
B	69(10.0)	65.(149.)	77.(170.)	118.(245.)	190.(374.)	225.(437.)	2.	591. (1240.)
C	79(11.5)	60.(140.)	77.(170.)	116.(240.)	185.(365.)	225.(437.)	2.	586. (1230.)
D	93(13.5)	55.(131.)	66.(150.)	113.(235.)	185.(365.)	225.(437.)	2.	580. (1220.)
E	103(15.0)	50.(122.)	66.(150.)	110.(230.)	185.(365.)	225.(437.)	2.	569. (1200.)

<sup>A</sup> Consult EPA for approved test methods for compliance with EPA vapor pressure regulations.

<sup>B</sup> At 101.3 kPa pressure (760 mm Hg).

<sup>C</sup> Driveability Index (DI) = 1.5 T<sub>10</sub> + 3.0 T<sub>50</sub> + 1.0 T<sub>90</sub>, where T<sub>10</sub> = distillation temperature, °C (°F), at 10 % evaporated, T<sub>50</sub> = distillation temperature, °C (°F), at 50 % evaporated, and T<sub>90</sub> = distillation temperature, °C (°F), at 90 % evaporated.

<sup>D</sup> The DI specification limits are applicable at the refinery or import facility as defined by 40 CFR Part 80.2 and are not subject to correction for precision of the test method.

<sup>E</sup> Since DI is an index and has no units, the standard temperature conversion from U.S. customary to SI units is not appropriate. The following equation is to be used to make the conversion:

$$DI_C = (DI_F - 176)/1.8$$

the rounding method of Practice E 29. The use of a trailing decimal point in a limit indicates that the digit preceding the decimal point is a significant digit.

1.8 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 only.

NOTE 2—Many of the values shown in Table 1 were originally developed using U.S. customary units and were subsequently soft-converted to SI values. As a result, conversion of the SI values will sometimes differ slightly from the U.S. customary values shown because of round-off. In some cases, federal regulations specify non-SI units.

1.9 The following safety hazard caveat pertains only to the test method portion, Annex A1 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:

- D 86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure<sup>3</sup>
- D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test<sup>3</sup>
- D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)<sup>3</sup>
- D 381 Test Method for Gum Content in Fuels by Jet Evaporation<sup>3</sup>
- D 439 Specification for Automotive Gasoline<sup>4</sup>
- D 525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)<sup>3</sup>
- D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)<sup>3</sup>
- D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method<sup>3</sup>

- D 2533 Test Method for Vapor-Liquid Ratio of Spark-Ignition Engine Fuels<sup>3</sup>
- D 2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-Ray Fluorescence Spectrometry<sup>3</sup>
- D 2699 Test Method for Research Octane Number of Spark-Ignition Engine Fuel<sup>3</sup>
- D 2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel<sup>3</sup>
- D 2885 Test Method for Research and Motor Method Octane Ratings Using On-Line Analyzers<sup>3</sup>
- D 3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry<sup>3</sup>
- D 3231 Test Method for Phosphorus in Gasoline<sup>5</sup>
- D 3237 Test Method for Lead in Gasoline by Atomic Absorption Spectrometry<sup>5</sup>
- D 3341 Test Method for Lead in Gasoline—Iodine Monochloride Method<sup>5</sup>
- D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter<sup>5</sup>
- D 4815 Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C<sub>1</sub> to C<sub>4</sub> Alcohols in Gasoline by Gas Chromatography<sup>5</sup>
- D 4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)<sup>5</sup>
- D 5059 Test Methods for Lead in Gasoline by X-Ray Spectroscopy<sup>5</sup>
- D 5188 Test Method for Vapor-Liquid Ratio Temperature Determination of Fuels (Evacuated Chamber Method)<sup>5</sup>
- D 5190 Test Method for Vapor Pressure of Petroleum Products (Automatic Method)<sup>5</sup>
- D 5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)<sup>5</sup>
- D 5453 Test Method for the Determination of Total Sulfur in Light Hydrocarbons, Motor Fuels, and Oils by Ultra-violet Fluorescence<sup>6</sup>

<sup>3</sup> Annual Book of ASTM Standards, Vol 05.01.

<sup>4</sup> Discontinued—See 1990 Annual Book of ASTM Standards, Vol 05.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 05.02.

<sup>6</sup> Annual Book of ASTM Standards, Vol 05.03.

**TABLE 2 Detailed Requirements for all Volatility Classes<sup>A</sup>**

Lead Content, max, g/L (g/U.S. gal) <sup>B</sup>		Copper Strip Corrosion, max	Solvent-washed Gum Content, mg/100 mL, max	Sulfur, max, mass %		Oxidation Stability, Minimum, minutes	Water Tolerance
Unleaded	Leaded			Unleaded	Leaded		
0.013(0.05)	1.1(4.2)	No. 1	5	0.10	0.15	240.	<sup>C</sup>

<sup>A</sup> See Appendix X1 for information on Antiknock Index.

<sup>B</sup> 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).

<sup>C</sup> Water tolerance limits in terms of maximum temperature for phase separation are given in Table 13.

D 5482 Test Method for Vapor Pressure of Petroleum Products (Mini Method-Atmospheric)<sup>6</sup>

D 5500 Test Method for Vehicle Evaluation of Unleaded Automotive Spark-Ignition Engine Fuel for Intake Valve Deposit Formation<sup>6</sup>

D 5598 Test Method for Evaluating Unleaded Automotive Spark-Ignition Engine Fuel for Electronic Port Fuel Injector Fouling<sup>6</sup>

D 5599 Test Method for Determination of Oxygenates in Gasoline by Gas Chromatography and Oxygen Selective Flame Ionization Detection<sup>6</sup>

D 5845 Test Method for Determination of MTBE, ETBE, TAME, DIPE, Methanol, Ethanol, and *tert*-Butanol in Gasoline by Infrared Spectroscopy<sup>6</sup>

D 6422 Test Method for Water Tolerance (Phase Separation) of Gasoline-Alcohol Blends<sup>7</sup>

D 6469 Guide for Microbial Contamination in Fuels and Fuel Systems<sup>7</sup>

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>8</sup>

**2.2 Government Standard:**

CFR 40 Code of Federal Regulations<sup>9</sup>

**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, generally 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 (more than 0.35 mass % oxygen, or more than 0.15 mass % oxygen if methanol is the only oxygenate) of one or more alcohols.

3.1.4 *gasoline-ether blend, n*—a fuel consisting primarily of gasoline along with a substantial amount (more than 0.35 mass % oxygen) of one or more ethers.

3.1.5 *gasoline-oxygenate blend, n*—a fuel consisting primarily of gasoline along with a substantial amount (more than 0.35 mass % oxygen, or more than 0.15 mass % oxygen if methanol is the only oxygenate) 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.

3.1.7 *refinery, n*—a plant at which gasoline or diesel fuel is produced.

3.1.7.1 *Discussion*—This definition is from CFR 40 Part 80.2. In the federal definition, a plant not only covers the conventional refinery, but also covers oxygenate blending and other facilities where gasoline is produced.

3.2 *Applicability*—To determine when a fuel contains a substantial amount of an oxygenate, a gasoline-oxygenate blend is defined as a fuel that contains more than 0.35 mass % oxygen, or more than 0.15 mass % 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 3—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.

NOTE 4—Refer to Test Method D 4815 to calculate the mass oxygen content of a fuel using oxygenate concentration in mass %. Refer to Appendix X4 to calculate mass oxygen content of a fuel using oxygenate concentration in volume %.

**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 2), 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. Test Method D 4815, a gas chromatographic test method, is the recommended procedure to detect the types and amounts of oxygenates. Once the type of fuel is known, the appropriate requirements and test methods can be identified by reference to Table 1 and Table 3 and Section 7.

5.2 Volatility of fuels is varied for seasonal climatic changes and conformance to U.S. EPA volatility regulations by providing six vapor pressure/distillation classes and six vapor lock protection classes for fuel. Volatility of fuel is specified by an alphanumeric designation that uses a letter from Table 1 and a number from Table 3.

5.2.1 The seasonal and geographic distribution of the combined vapor pressure/distillation-vapor lock classes is shown in Table 4. Tables 5-7 show the federal ozone nonattainment areas at several vapor lock protection levels that require reduced

<sup>7</sup> Annual Book of ASTM Standards, Vol 05.04.

<sup>8</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>9</sup> Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.



**TABLE 3 Vapor Lock Protection Class Requirements**

Vapor Lock Protection Class	Vapor/Liquid Ratio (V/L) <sup>A,B</sup>	
	Test Temperature, °C (°F)	V/L, max
1	60.(140.)	20
2	56.(133.)	20
3	51.(124.)	20
4	47.(116.)	20
5	41.(105.)	20
6	35.(95.)	20

<sup>A</sup> At 101.3 kPa pressure (760 mm Hg).

<sup>B</sup> 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. Test Method D 5188 may be used for all fuels. The procedure for estimating temperature-V/L (see Appendix X2) may only be used for gasoline.

vapor pressure in the summertime. Tables 8-11 show at several vapor lock protection levels the areas that require federal reformulated spark-ignition engine fuel in the summertime.

Table 12 shows the areas with restrictive local vapor pressure limits that have been approved under the EPA state implementation plan (SIP).

**TABLE 4 Schedule of Seasonal and Geographical Volatility Classes<sup>A</sup>**

NOTE 1—This schedule, subject to agreement between purchaser and seller, denotes the volatility properties of the fuel at the time and place of bulk delivery to the fuel dispensing facilities for the end user. For Sept. 16 through April 30 (the time period not covered by EPA Phase II vapor pressure requirements), volatility properties for the previous month or the current month are acceptable for the end user from the 1st through the 15th day of the month. From the 16th day through the end of the month, volatility properties of the fuel delivered to the end user shall meet the requirements of the specified class(es). To ensure compliance with EPA Phase II vapor pressure requirements, vapor pressure for finished gasoline tankage at refineries, importers, pipelines, and terminals during May and for the entire distribution system, including retail stations, from June 1 to Sept. 15 shall meet only the current month's class. Shipments should anticipate this schedule.

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

NOTE 3—See Appendix X2 of Research Report: D02-1347 (available from ASTM International Headquarters) for detailed description of areas. Contact EPA for the latest information on areas requiring reformulated fuel.

State	Jan.	Feb.	Mar.	Apr.	May <sup>B</sup>	June	July	Aug.	Sept. 1-15	Sept. 16-30	Oct.	Nov.	Dec.
Alabama	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/C-3	C-3	C-3/D-4	D-4
Alaska	E-6	E-6	E-6	E-6	E-6/D-4	D-4	D-4	D-4	D-4	D-4/E-6	E-6	E-6	E-6
Arizona: <sup>E</sup>													
N 34° Latitude and E111° Longitude	D-4	D-4	D-4/C-3	C-3/A-2	A-2 (B-2)	A-1	A-1	A-1	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4
Remainder of State	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1 <sup>F</sup>	A-1 <sup>F</sup>	A-1 <sup>F</sup>	A-1 <sup>D</sup>	A-1	A-1/B-2	B-2/C-3	C-3/D-4
Arkansas	E-5/D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4	D-4/E-5
California: <sup>E,G</sup>													
North Coast	E-5/D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
South Coast	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4
Southeast	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1 <sup>F</sup>	A-1 <sup>F,I</sup>	A-1 <sup>F,I</sup>	A-1 <sup>F,I</sup>	A-1	A-1/B-2	B-2/C-3	C-3/D-4
Interior	E-5/D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Colorado	E-5	E-5/D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Connecticut	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/D-4	D-4	D-4/E-5	E-5
Delaware	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
District of Columbia	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3 <sup>K</sup>	A-3 <sup>K</sup>	A-3 <sup>K</sup>	A-3 <sup>K</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Florida	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-3/C-3	C-3	C-3/D-4	D-4
Georgia: <sup>E</sup>	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/C-3	C-3	C-3/D-4	D-4
Hawaii	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3	C-3
Idaho:													
N 46° Latitude	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4/E-5	E-5
S 46° Latitude	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Illinois: <sup>E</sup>													
N 40° Latitude	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
S 40° Latitude	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4	D-4/E-5
Indiana: <sup>E</sup>	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Iowa	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Kansas: <sup>E</sup>	E-5	E-5/D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Kentucky	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Louisiana	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/C-3	C-3	C-3/D-4	D-4
Maine: <sup>E</sup>	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/D-4	D-4	D-4/E-5	E-5
Maryland	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J,K</sup>	A-3 <sup>J,K</sup>	A-3 <sup>J,K</sup>	A-3 <sup>J,K</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Massachusetts	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/D-4	D-4	D-4/E-5	E-5
Michigan: <sup>E</sup>	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/D-4	D-4	D-4/E-5	E-5
Minnesota	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Mississippi	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3	A-3	A-2	A-2	A-2/C-3	C-3	C-3/D-4	D-4

**TABLE 4** *Continued*

State	Jan.	Feb.	Mar.	Apr.	May <sup>B</sup>	June	July	Aug.	Sept. 1–15	Sept. 16–30	Oct.	Nov.	Dec.
Missouri <sup>E</sup>	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/C-3	C-3/D-4	D-4	D-4/E-5
Montana	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4/E-5	E-5
Nebraska	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Nevada:													
N 38° Latitude	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
S 38° Latitude	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1	A-1	A-1	A-1	A-1	A-1/B-2	B-2/C-3	C-3/D-4
New Hampshire	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/D-4	D-4	D-4/E-5	E-5
New Jersey	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/D-4	D-4	D-4/E-5	E-5
New Mexico:													
N 34° Latitude	E-5/D-4	D-4	D-4/C-3	C-3/A-2	A-2 (B-2)	A-1	A-1	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4
S 34° Latitude	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1	A-1	A-1	A-1	A-1/B-2	B-2/C-3	C-3/D-4	D-4
New York	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/D-4	D-4	D-4/E-5	E-5
North Carolina	E-5/D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/C-3	C-3/D-4	D-4	D-4/E-5
North Dakota	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4/E-5	E-5
Ohio	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Oklahoma	E-5/D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Oregon:													
E 122° Longitude	E-5	E-5/D-4	D-4	D-4/A-4	A-4 (D-4)	A-3	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4	D-4/E-5
W 122° Longitude	E-5	E-5/D-4	D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Pennsylvania <sup>E</sup>	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3	A-3/D-4	D-4	D-4/E-5	E-5
Rhode Island	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3	A-3/D-4	D-4	D-4/E-5	E-5
South Carolina	D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-3	A-3	A-2	A-2	A-2/C-3	C-3/D-4	D-4	D-4
South Dakota	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Tennessee	E-5/D-4	D-4	D-4	D-4/A-3	A-3 (C-3)	A-3 <sup>C</sup>	A-3 <sup>C</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/C-3	C-3/D-4	D-4	D-4/E-5
Texas: <sup>E</sup>													
E 99° Longitude	D-4	D-4	D-4/C-3	C-3/A-3	A-3 (C-3)	A-3 <sup>C,K</sup>	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2 <sup>D,H</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4
W 99° Longitude	D-4	D-4/C-3	C-3/B-2	B-2/A-2	A-2 (B-2)	A-1 <sup>F</sup>	A-1 <sup>F</sup>	A-1 <sup>F</sup>	A-1 <sup>F</sup>	A-1/B-2	B-2/C-3	C-3/D-4	D-4
Utah	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2 <sup>D</sup>	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5
Vermont	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/D-4	D-4	D-4/E-5	E-5
Virginia	E-5	E-5/D-4	D-4	D-4/A-3	A-3 (C-3)	A-3 <sup>C,K</sup>	A-3 <sup>C,K</sup>	A-3 <sup>C,K</sup>	A-3 <sup>C,K</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Washington:													
E 122° Longitude	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-2	A-2	A-2	A-2/C-3	C-3/D-4	D-4/E-5	E-5
W 122° Longitude	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
West Virginia	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3	A-3	A-3	A-3	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Wisconsin	E-5	E-5	E-5/D-4	D-4/A-4	A-4 (D-4)	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3 <sup>J</sup>	A-3/C-3	C-3/D-4	D-4/E-5	E-5
Wyoming	E-5	E-5	E-5/D-4	D-4/A-3	A-3 (C-3)	A-2	A-2	A-2	A-2	A-2/B-2	B-2/C-3	C-3/D-4	D-4/E-5

<sup>A</sup> For the period May 1 through September 15, the specified vapor pressure classes comply with 1992 U.S. EPA Phase II volatility regulations. Reformulated spark-ignition engine fuel blended to meet the requirements of the EPA "Complex Model" shall also meet the Phase II volatility regulations. EPA regulations (under the Phase II regulations) allow 1.0 psi higher vapor pressure for gasoline-ethanol blends containing 9 to 10 volume % ethanol for the same period, except for fuels blended to meet the "Complex Model" regulations. See Appendix X3 for additional federal volatility regulations.

<sup>B</sup> Values in parentheses are permitted for retail stations and other end users.

<sup>C</sup> See Table 5 for specific area requirements.

<sup>D</sup> See Table 6 for specific area requirements.

<sup>E</sup> See Table 12 for specific area requirements.

<sup>F</sup> See Table 7 for specific area requirements.

<sup>G</sup> 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 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).

<sup>H</sup> See Table 10 for specific requirements.

<sup>I</sup> See Table 11 for specific area requirements.

<sup>J</sup> See Table 8 for specific area requirements.

<sup>K</sup> See Table 9 for specific area requirements.

5.2.2 The EPA vapor pressure regulations can cause the distillation of the fuel to be less volatile, which for some vehicles, results in poorer warm-up driveability performance.

5.2.3 Driveability Index (DI) is intended to provide control of distillation parameters that influence cold start and warm-up driveability. It is a function of the 10 %, 50 %, and 90 % evaporated distillation temperatures measured by Test Method D 86.

5.2.4 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. Test Method D 5188 is an alternative method for determining vapor-liquid ratio temperatures by an evacuated chamber method for gasoline-oxygenate blends, as well as gasoline. In case of

**TABLE 5 Ozone Nonattainment Areas Requiring Volatility Class AA-3**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

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Alabama <sup>A</sup> —Jefferson and Shelby counties
California <sup>A</sup> —Alameda, Contra Costa, Marin, Monterey, Napa, San Francisco, San Benito, San Mateo, Santa Clara, Santa Cruz, and Solano (part) counties
Florida—Broward, Dade, Duval, Hillsborough, Palm Beach, and Pinellas counties
Georgia <sup>A</sup> —Cherokee, Clayton, Cobb, Coweta, Dekalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, and Rockdale counties
Louisiana—Ascension, Beauregard, Calcasieu, East Baton Rouge, Grant, Iberville, Jefferson, Lafayette, Lafourche, Livingston, Orleans, Point Coupee, Saint Bernard, Saint Charles, Saint James, Saint Mary, and West Baton Rouge parishes
Missouri—Franklin, Jefferson, Saint Charles, and Saint Louis counties; and the city of St. Louis
North Carolina—Davidson, Davie (part), Durham, Forsyth, Gaston, Granville (part), Guilford, Mecklenburgh, and Wake counties
Oregon—Clackamas (part), Marion (part), Multnomah (part), Polk (part), and Washington (part) counties
Tennessee—Davidson, Rutherford, Shelby, Sumner, Williamson, and Wilson counties
Texas—Hardin, Jefferson, Orange, and Victoria counties
Virginia—Smyth County (part)

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<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 6 Ozone Nonattainment Areas Requiring Volatility Class AA-2**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

---

Alabama <sup>A</sup> —Jefferson and Shelby counties
Arizona <sup>A</sup> —Maricopa County
California <sup>A</sup> —Alameda, Butte, Contra Costa, Fresno, Kern (part) Kings, Madiera, Marin, Merced, Monterey, Napa, San Benito, San Francisco, San Joaquin, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Stanislaus, Tulare, and Yuba counties
Colorado—Adams, Arapahoe, Boulder, Denver, Douglas, and Greeley counties (waived by EPA)
Georgia <sup>A</sup> —Cherokee, Clayton, Cobb, Coweta, Dekalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Henry, Paulding, and Rockdale counties
Kansas <sup>A</sup> —Johnson and Wyandotte counties
Louisiana—Ascension, Beauregard, Calcasieu, East Baton Rouge, Grant, Iberville, Jefferson, Lafayette, Lafourche, Livingston, Orleans, Point Coupee, Saint Bernard, Saint Charles, Saint James, Saint Mary, and West Baton Rouge parishes
Missouri—Franklin, Jefferson, Saint Charles, and Saint Louis counties; and the city of St. Louis
Nevada—Washoe County
North Carolina—Davidson, Davie (part), Durham, Forsyth, Gaston, Granville (part), Guilford, Mecklenburgh, and Wake counties
Tennessee—Davidson, Rutherford, Shelby, Sumner, Williamson, and Wilson counties
Texas—Hardin, Jefferson, Orange, and Victoria counties
Utah—Davis and Salt Lake counties

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<sup>A</sup> See Table 12 for local vapor pressure limits.

dispute, Test Method D 2533 is the referee method. The method for estimating temperature-*V/L* (see Appendix X2) is only applicable for gasoline.

5.3 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

**TABLE 7 Ozone Nonattainment Areas Requiring Volatility Class AA-1**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

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Arizona <sup>A</sup> —Maricopa County
California <sup>A</sup> —Imperial and Kern (part) counties
Texas <sup>A</sup> —El Paso County

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<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 8 Federal RFG Areas Requiring Volatility Class A-3**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

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Connecticut—All counties
Delaware—All counties
Illinois <sup>A</sup> —Cook, Du Page, Grundy (part), Kane, Kendall (part), Lake, McHenry, and Will counties
Indiana <sup>A</sup> —Lake and Porter counties
Kentucky—Boone, Bullitt (part), Campbell, Jefferson, Kenton, and Oldham (part) counties
Maryland—Cecil County
Massachusetts—All counties
New Hampshire—Hillsborough, Merrimack, Rockingham, and Strafford counties
New Jersey—All counties
New York—Bronx, Dutchess, Essex (part), Kings, Nassau, New York, Orange, Putnam, Queens, Richmond, Rockland, Suffolk, and Westchester counties
Pennsylvania—Bucks, Chester, Delaware, Montgomery, and Philadelphia counties
Rhode Island—All counties
Wisconsin—Kenosha, Milwaukee, Ozaukee, Racine, Washington, and Waukesha counties

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<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 9 Federal RFG Areas Requiring Volatility Class AA-3**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

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District of Columbia
Maryland—Anne Arundel, Baltimore, Calvert, Carroll, Charles, Frederick, Harford, Howard, Kent, Montgomery, Prince George's, and Queen Anne's counties
Texas—Brazoria, Chambers, Collin, Dallas, Denton, Fort Bend, Galveston, Harris, Liberty, Montgomery, Tarrant, and Waller counties
Virginia—Arlington, Charles City, Chesterfield, Fairfax, Hanover, Henrico, James City, Loudoun, Prince William, Stafford, and York counties and independent cities of Alexandria, Chesapeake, Colonial Heights, Fairfax, Falls Church, Hampton, Hopewell, Manassas, Manassas Park, Newport News, Norfolk, Poquoson, Portsmouth, Richmond, Suffolk, Virginia Beach, and Williamsburg

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broad groups of engines and vehicles. Also discussed is the effect of altitude and weather on vehicle antiknock requirements.

5.4 Additional fuel requirements are shown in Table 2.

5.5 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

**TABLE 10 Federal RFG Areas Requiring Volatility Class AA-2**

NOTE 1—See 40 CFR Part 81.305 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

California<sup>A</sup>—El Dorado (part), Los Angeles, Orange, Placer (part), Riverside (part), Sacramento, San Bernardino (part), San Diego, Solano (part), Sutter (part), Ventura, and Yolo Counties

Texas—Brazoria, Chambers, Collin, Dallas, Denton, Fort Bend, Galveston, Harris, Liberty, Montgomery, Tarrant, and Waller counties

<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 11 Federal RFG Area Requiring Volatility Class AA-1**

NOTE 1—See 40 CFR Part 81.300 for description of the geographic boundary for each area.

NOTE 2—No waiver for gasoline-ethanol blends.

California<sup>A</sup>—Los Angeles (part), Riverside (part), and San Bernardino (part) counties

<sup>A</sup> See Table 12 for local vapor pressure limits.

**TABLE 12 Federal Approved State Implementation Plan Areas Requiring More Restrictive Maximum Vapor Pressure Limits**

NOTE 1—Some areas are awaiting official EPA approval for the more restrictive local vapor pressure limits.

Alabama—Jefferson and Shelby counties—48.2 kPa (7.0 psi) max June 1 - Sept. 15

Arizona—Maricopa County—48.2 kPa (7.0 psi) max May 31 - Sept. 30, 62.0 kPa (9.0 psi) max Oct. 1 - Mar. 31

California—48.26 kPa (7.00 psi) max April 1, May 1, or June 1 - Sept. 30 or Oct. 31 depending on air basin

Georgia—Barrow, Bartow, Butts, Carroll, Cherokee, Clayton, Cobb, Coweta, Dawson, DeKalb, Douglas, Fayette, Forsyth, Fulton, Gwinnett, Hall, Haralson, Henry, Jackson, Newton, Paulding, Pickens, Rockdale, Spalding, and Walton counties—48.2 kPa (7.0 psi) max June 1 - Sept 15<sup>A</sup>

Illinois—Madison, Monroe, and Saint Clair Counties area - 49.6 kPa (7.2 psi) max June 1 - Sept. 15<sup>A</sup>

Indiana—Clark and Floyd counties area - 53.8 kPa (7.8 psi) max May 1 terminal/June 1 retail - Sept. 15<sup>A</sup>

Kansas—Johnson and Wyandotte counties—48.2 kPa (7.0 psi) max June 1 - Sept. 15<sup>A</sup>

Maine—Androscoggin, Cumberland, Kennebec, Knox, Lincoln, Sagadahoc, and York Counties—49.6 kPa (7.2 psi) max May 1-Sept 15

Michigan—Livingston, Macomb, Monroe, Oakland, Saint Clair, Washtenaw, and Wayne counties—53.8 kPa (7.8 psi) max June 1 - Sept 15

Missouri—Clay, Jackson, and Platte counties—48.2 kPa (7.0 psi) max June 1 - Sept. 15<sup>A</sup>

Pennsylvania—Allegheny, Armstrong, Beaver, Butler, Fayette, Washington, and Westmoreland counties—53.8 kPa (7.8 psi) max June 1 - Sept. 15

Texas—El Paso County—48.2 kPa (7.0 psi) max May 1 terminal/June 1 retail - Sept. 15

Texas—Anderson, Angelina, Aransas, Atascosa, Austin, Bastrop, Bee, Bell, Bexar, Bosque, Bowie, Brazos, Burleson, Caldwell, Calhoun, Camp, Cass, Cherokee, Colorado, Comal, Cooke, Coryell, De Witt, Delta, Ellis, Falls, Fannin, Fayette, Franklin, Freestone, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Harrison, Hays, Henderson, Hill, Hood, Hopkins, Houston, Hunt, Jackson, Jasper, Johnson, Karnes, Kaufman, Lamar, Lavaca, Lee, Leon, Lime-stone, Live Oak, Madison, Marion, Matagorda, McLennan, Milam, Morris, Nacogdoches, Nararro, Newton, Nueces, Panola, Parker, Polk, Rains, Red River, Refugio, Robertson, Rockwall, Rusk, Sabine, San Jacinto, San Patricio, San Augustine, Shelby, Smith, Somervell, Titus, Travis, Trinity, Tyler, Upshur, Van-Zandt, Victoria, Walker, Washington, Wharton, Williamson, Wilson, Wise, and Wood counties—48.2 kPa (7.0 psi) max May 1 terminal/June 1 retail - October 1

<sup>A</sup> A 1.0 psi higher vapor pressure is allowed for gasoline-ethanol blends containing 9 to 10 volume % ethanol.

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 13.

5.6 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.

#### 5.7 Water Tolerance:

5.7.1 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 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-alcohol 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 13. The values in Table 13 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 13 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 5—The values in Table 13 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.

5.7.2 The water tolerance test procedure consists of cooling gasoline-alcohol blends under specified conditions to the appropriate temperature listed in Table 13. It is important to note that when cooling to a low temperature some gasoline-alcohol blends can take on a hazy appearance. This haze must be carefully distinguished from the phase separation test criterion described in Test Method D 6422 and must not be considered grounds for rejection of the fuel. This test must not be confused with that described in Section 6 (Workmanship), which is conducted at 21°C (70°F) or above, and for which the appearance of haze is proper grounds for rejection.



**TABLE 13 Maximum Temperature for Phase Separation, °C<sup>A</sup>**

State	Temperature Conversion °F = (°C × 1.8) + 32°											
	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.
<sup>B</sup> 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.
<sup>C</sup> 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.
<sup>D</sup> 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.
Texas:												
N of 31° Latitude	-11.	-8.	-4.	2.	8.	10.	10.	10.	10.	5.	-3.	-7.



**TABLE 13** *Continued*

State	Temperature Conversion °F = (°C × 1.8) + 32°											
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
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.

<sup>A</sup> 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.

<sup>B</sup> 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.

<sup>C</sup> 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).

<sup>D</sup> 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.

5.8 Deposit control additives are added to fuel to help keep carburetors, fuel injectors, and intake valves clean. Deposit control additives are required to be certified by EPA as summarized in X3.5. Each additive is certified for use at a lowest additive concentration (LAC), which is the lowest level certified to be effective in preventing deposit formation. All parties who blend deposit control additives into fuel must complete mandatory volume additive reconciliation (VAR) accounting to establish that the product was added at a concentration that was at least equal to the LAC.

## 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.

6.3 The finished fuel shall also be free of any adulterant or contaminant that may render the fuel unacceptable for its commonly used applications.

## 7. Test Methods

7.1 The requirements of this specification shall be determined in accordance with the methods listed below. Refer to the listed test methods to determine applicability or required modifications for use with gasoline-oxygenate blends.

7.1.1 *Distillation*—Test Method D 86.

7.1.2 *Vapor-Liquid Ratio*—Test Method D 2533 has procedures for determining vapor-liquid (V/L) ratios for both gaso-

line 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. Test Method D 5188 is an evacuated chamber method for determining temperatures for vapor-liquid ratios between 8 to 1 and 75 to 1. It may be used for gasoline and gasoline-oxygenate blends.

7.1.3 *Vapor Pressure*—Test Methods D 4953, D 5190, D 5191, or D 5482.

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

7.1.5 *Solvent-Washed Gum Content*—Test Method D 381, air jet apparatus.

7.1.6 *Sulfur*—Test Methods D 1266, D 2622, D 3120, or D 5453. 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 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 3237 or D 5059 (Test Method C).

7.1.8 *Oxidation Stability*—Test Method D 525.

7.1.9 *Oxygenate Detection*—Test Methods D 4815, D 5599, or D 5845. These test methods are designed for the quantitative determination of methyl *tert*-butyl ether (MTBE), ethyl *tert*-butyl ether (ETBE), *tert*-amyl methyl ether (TAME), diisopropyl ether (DIPE), methyl alcohol, ethyl alcohol, and *tert*-butyl alcohol. In addition, Test Methods D 4815 and D 5599 are designed for the quantitative determination of *n*-propyl alcohol, *isopropyl* alcohol, *n*-butyl alcohol, *sec*-butyl alcohol *isobutyl* alcohol and *tert*-pentyl alcohol. Results for all these

test methods are reported in mass %. Test Method D 4815 includes procedures for calculating oxygenate concentration in volume % and mass oxygen content using the mass % oxygenate results.

7.1.10 *Water Tolerance*—See Test Method D 6422.

## 8. Precision and Bias<sup>10</sup>

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

8.2 *Precision and Bias of Driveability Index (DI)*:

8.2.1 The following statements apply to the precision and bias of DI, which is a derived quantity not addressed in any other standard.<sup>10</sup>

8.2.2 The precision of DI is a function of the individual precisions of the 10 %, 50 %, and 90 % evaporated temperatures from Test Method D 86. The precisions of these percent evaporated temperatures vary for different apparatuses (manual or automatic), for fuels of different volatilities [for example, above and below 65.5 kPa (9.5 psi) vapor pressure] and with different distillation curve slopes.

8.2.3 *Repeatability*—The difference between two successive DI determinations using Test Method D 86 results, where the two test results were obtained by one operator with the same apparatus under constant operating conditions on identical test material, would in the long run, in normal and correct operation of the test method, exceed 9°C (17°F) derived units in only one case in twenty.

8.2.4 The repeatability value was calculated using the precision data from Test Method D 86 and average distillation characteristics from the 1994 through 1998 ASTM Committee

D02 Interlaboratory Crosscheck Program for Motor Gasoline and from the 1997 and 1998 ASTM Committee D02 Interlaboratory Crosscheck Program for Reformulated Gasoline.

8.2.5 *Reproducibility*—The difference between two single and independent DI determinations using Test Method D 86 results, where the two test results were obtained by different operators in different laboratories on identical test material, would in the long run, in normal and correct operation of the test method, exceed 27°C (48°F) derived units in only one case in twenty.

8.2.6 The reproducibility values were determined directly using the distillation data from each laboratory participating in cooperative programs to calculate DI. The data used to calculate DI were available from the 1994 through 1998 ASTM Committee D02 Interlaboratory Crosscheck Program for Motor Gasoline, the 1997 and 1998 ASTM Committee D02 Interlaboratory Crosscheck Program for Reformulated Gasoline, the Auto/Oil Air Quality Improvement Research Program, the Auto/Oil AAMA Gasoline Inspections Program, and the 1995 - 1996 CRC volatility program.

8.2.7 *Bias*—Since there is no acceptable reference material suitable for determining bias for DI, bias has not been determined.

## 9. Keywords

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

## APPENDIXES

### (Nonmandatory Information)

## X1. SIGNIFICANCE OF ASTM SPECIFICATION FOR AUTOMOTIVE SPARK-IGNITION ENGINE FUEL

### X1.1 General

X1.1.1 Antiknock rating and volatility define the general characteristics of automotive spark-ignition engine fuel. Other characteristics relate to the following: limiting the concentration of undesirable components so that they will not adversely affect engine performance and ensuring the stability of fuel as well as its compatibility with materials used in engines and their fuel systems.

X1.1.2 Fuel for spark-ignition engines is a complex mixture composed of relatively volatile hydrocarbons that vary widely in their physical and chemical properties and may contain oxygenates. Fuel is exposed to a wide variety of mechanical, physical, and chemical environments. Thus, the properties of

fuel must be balanced to give satisfactory engine performance over an extremely wide range of operating conditions. The prevailing standards for fuel represent compromises among the numerous quality and performance requirements. This ASTM specification is established on the basis of the broad experience and close cooperation of producers of fuel, manufacturers of automotive equipment, and users of both.

### X1.2 Engine Knock

X1.2.1 The fuel-air mixture in the cylinder of a spark-ignition engine will, under certain conditions, autoignite in localized areas ahead of the flame front that is progressing from the spark. This is engine spark knock which can cause a ping that may be audible to the customer.

<sup>10</sup> Supporting data (calculations) have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1468.