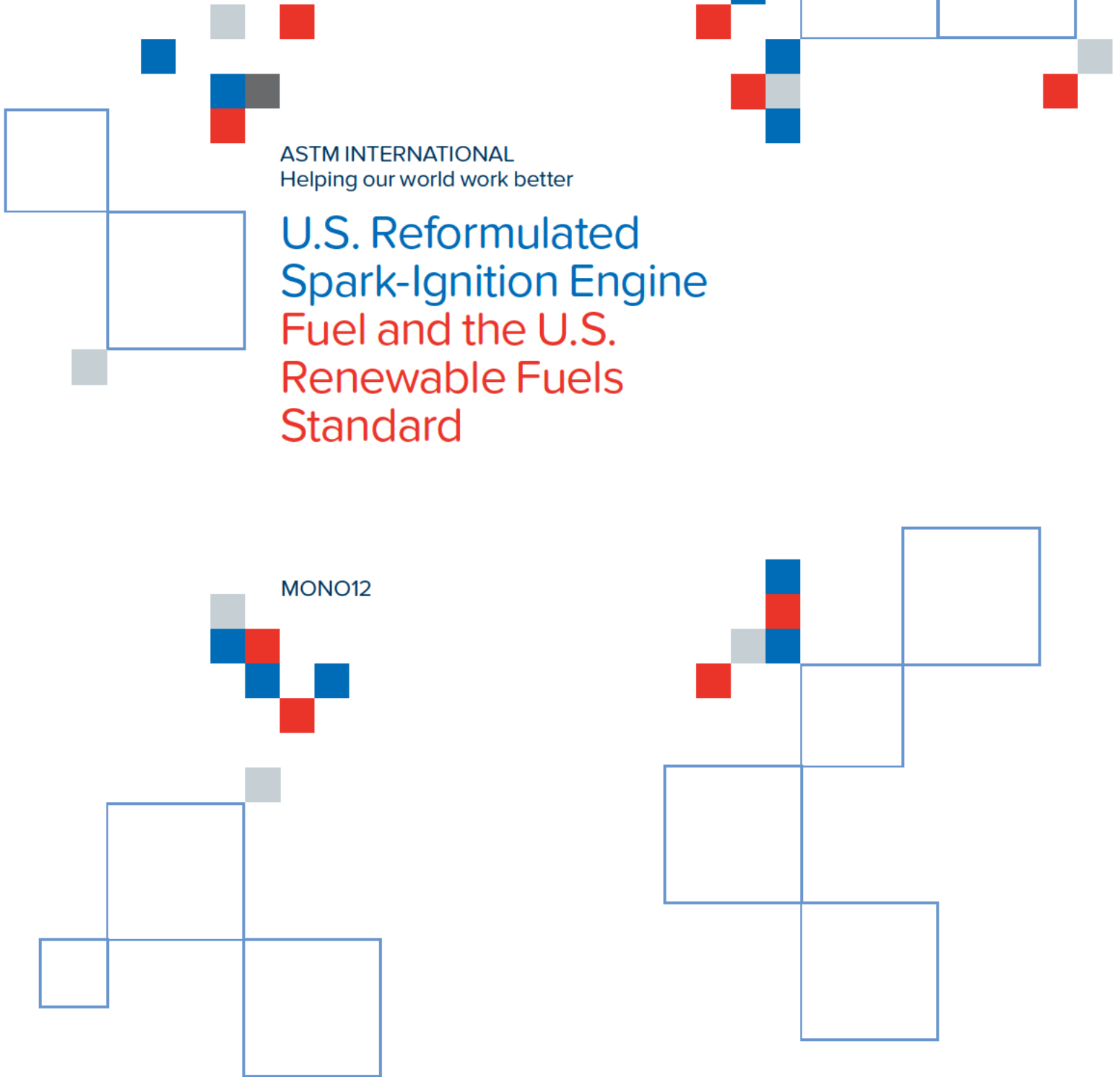




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U.S. Reformulated Spark-Ignition Engine Fuel and the U.S. Renewable Fuels Standard

MONO12





U.S. Reformulated Spark-Ignition Engine Fuel and the U.S. Renewable Fuels Standard

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Foreword

THIS PUBLICATION, *U.S. Reformulated Spark-Ignition Engine Fuel and the U.S. Renewable Fuels Standard*, was prepared by members of Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants. It was formerly Research Report D02: 1347.

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Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants Report D02: 1347

Report on U.S. Reformulated Spark-Ignition Engine Fuel and the U.S. Renewable Fuels Standard

March 2016

1. Scope

1.1 This report is published to provide information on the requirements of federal reformulated gasoline and EPA approved state fuel requirements in the United States for ground vehicles equipped with spark-ignition engines.

1.2 This report describes various characteristics of reformulated fuels required for use in automotive vehicles within severe and extreme ozone nonattainment areas as designated by the Clean Air Act Amendments (CAAA) of 1990 and in those ozone nonattainment areas that opt in to the federal reformulated gasoline program or require certain EPA approved state fuels in their State Implementation Plans. This report also describes limitations, where adopted, on fuel composition and properties established by federal regulations or the state of California. Additionally, this report describes renewable fuels requirements, which are not part of federal reformulated or state approved gasoline requirements, but apply to producers of all gasoline including those that produce reformulated gasoline or state fuels. This report neither necessarily includes all types of fuels that are satisfactory for automotive vehicles, nor necessarily excludes fuels that may perform unsatisfactorily under certain operating conditions or in certain equipment. The significance of each fuel property contained in this report is shown in Appendix X1.

1.3 The reformulated fuels covered in this report are unleaded gasolines, generally blended with oxygenates such as ethanol. The requirements of federal reformulated fuels have been established by the U. S. Environmental Protection Agency (EPA). In the state of California, requirements for California reformulated gasoline have been set by the California Air Resources Board (CARB). Under provisions and within certain restrictions of the CAAA, other states may petition the EPA to require the use of federal reformulated gasoline or EPA-approved State Implementation Plan fuels in specific areas.

1.4 This report provides information on states that are part of the Federal Reformulated Gasoline Program or that have EPA approved cleaner burning gasoline requirements in their State Implementation Plans. In addition to California, Arizona has adopted a cleaner burning gasoline standard. Fuel requirements for state reformulated gasoline programs are provided in Appendix X3.

1.5 The various characteristics of reformulated fuels described in this report are legal requirements imposed by regulatory

agencies to lower exhaust and evaporative emissions from automotive vehicles.

1.6 This report represents a description of reformulated fuel as of the date of publication¹. This report is under continual review, which will result in revisions based on changes in regulations, fuels, automotive requirements, or test methods, or a combination thereof. All users should refer to the latest edition of this report and should also refer to the regulations published in the Code of Federal Regulations and the California Code of Regulations for guidance on compliance. Contact the EPA for the latest version of EPA rules and requirements. EPA fuels and fuel additive rule-makings can be found on the Electronic Code of Federal Regulations (e-CFR) website at <http://www.ecfr.gov/>, specifically 40 CFR parts 79 and 80. Users should also refer to state regulations for recent changes. Some test methods are not acceptable to all regulatory agencies.

1.7 Enforcement of many of the federal regulations for individual properties described in this report occurs only at the refinery or import facility. Per gallon maximum or minimum limits for averaging (see [Table 1](#)) and the requirement for the addition of detergent additives are also enforced in the downstream distribution system at terminals and retail outlets. Users of this report should contact the EPA for information regarding enforcement policies in the distribution system. California regulations apply at all levels of the distribution system.

1.8 The values stated in this report are primarily U.S. customary units specified by Federal and state regulatory agencies.

2. Referenced Documents

2.1 ASTM STANDARDS

D86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure

D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)

D1159 Test Method for Bromine Numbers of Petroleum Distillates and Commercial Aliphatic Olefins by Electrometric Titration

D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption

¹ If there is any doubt as to the latest edition of this report, contact ASTM headquarters.

D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-Ray Fluorescence Spectrometry

D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry

D3606 Test Method for Determination of Benzene and Toluene in Finished Motor and Aviation Gasoline by Gas Chromatography

D4045 Test Method for Sulfur in Petroleum Products by Hydrogenolysis and Rateometric Colorimetry

D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-Ray Fluorescence Spectrometry

D4806 Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark-Ignition Engine Fuel

D4814 Specification for Automotive Spark-Ignition Engine Fuel

D4815 Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C1 to C4 Alcohols in Gasoline by Gas Chromatography

D4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)

D5191 Test Method for Vapor Pressure of Petroleum Products (Mini Method)

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

D5482 Test Method for Vapor Pressure of Petroleum Products (Mini Method – Atmospheric)

D5500 Test Method for Vehicle Evaluation of Unleaded Automotive Spark-Ignition Engine Fuel for Intake Valve Deposit Formation

D5580 Test Method for the Determination of Benzene, Toluene, Ethylbenzene, p/m-Xylene, o-Xylene, C₉ and Heavier Aromatics, and Total Aromatics in Finished Gasoline by Gas Chromatography

D5598 Test Method for Evaluating Unleaded Automotive Spark-Ignition Engine Fuel for Electronic Port Fuel Injector Fouling

D5599 Test Method for the Determination of Oxygenates in Gasoline by Gas Chromatography and Oxygen Selective Flame Ionization Detection

D5622 Test Methods for Determination of Total Oxygen in Gasoline and Methanol Fuels by Reductive Pyrolysis

D5769 Test Method for Determination of Benzene, Toluene and Total Aromatics in Finished Gasolines by Gas Chromatography/Mass Spectrometry

D5845 Test Method for Determination of MTBE, ETBE, TAME, DIPE, Methanol, Ethanol and tert-Butanol in Gasoline by Infrared Spectroscopy

D5986 Test Method for Determination of Oxygenates, Benzene, Toluene, C₈-C₁₂ Aromatics and Total Aromatics in Finished Gasoline by Gas Chromatography/Fourier Transform Infrared Spectroscopy

D6277 Test Method for Determination of Benzene in Spark-Ignition Engine Fuels Using Mid Infrared Spectroscopy

D6378 Test Method for Determination of Vapor Pressure (VP_x) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)

D6550 Test Method for Determination of Olefin Content of Gasolines by Supercritical-Fluid Chromatography

D6920 Test Method for Total Sulfur in Naphthas, Distillates, Reformulated Gasolines, Diesels, Biodiesels, and Motor Fuels by Oxidative Combustion and Electrochemical Detection

D7039 Test Method for Sulfur in Gasoline, Diesel Fuel, Jet Fuel, Kerosine, Biodiesel, Biodiesel Blends, and Gasoline-Ethanol Blends by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry

D7754 Test Method for Determination of Trace Oxygenates in Automotive Spark-Ignition Engine Fuel by Multidimensional Gas Chromatography

3. Terminology

3.1 DEFINITIONS

3.1.1 *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.

3.1.2 *gasoline-alcohol blend, n* - a fuel consisting primarily of gasoline along with a substantial amount (more than 0.35 mass percent oxygen, or more than 0.15 mass percent oxygen if methanol is the only oxygenate) of one or more alcohols.

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

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

3.1.5 *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 *Description of Terms Specific to This Report:*

3.2.1 *Adjusted VOC gasoline* - a gasoline that contains 10 to 15 % by volume percent ethanol, or RBOB intended for blending with 10 to 15 % by volume percent ethanol, that is intended for use in the VOC-Control Region 2 RFG covered areas of Chicago and Milwaukee, and is designated by the refiner as “adjusted VOC gasoline” subject to less stringent Federal EPA VOC standards. The concentration of the ethanol, excluding denaturant, of the finished RFG must be at least 9 % and no more than 15 % by volume of the gasoline.

3.2.2 *Adjusted VOC gasoline standards* - the applicable VOC performance standards in 40 CFR §80.41 for adjusted VOC gasoline intended for use in or sold for use by an ultimate consumer in VOC-Control Region 2 in the RFG covered areas of Chicago and Milwaukee.

3.2.3 *alternative gasoline formulation* - a gasoline or gasoline-oxygenate blend that does not meet the fuel parameter requirements for California Phase 3 reformulated Gasoline (CaRFG3) but has been certified by CARB to result in equivalent emissions reductions, by CARB’s acceptance of emissions data from vehicle testing or from prediction by the California Predictive Model.

3.2.4 *anti-dumping* - a provision of the 1990 Clean Air Act Amendments intended to ensure that fuel components, which

increase emissions, and are removed or limited in reformulated gasoline, are not added or “dumped” into conventional gasoline.

3.2.5 *averaging* - a process whereby a value for a parameter that is above the standard in one reformulated gasoline batch can be offset by a value that is below the standard in another batch for a given refiner or importer.

3.2.6 *average limit* - a restriction on a reformulated gasoline parameter that shall be met on average during a yearly or seasonal reporting period.

3.2.7 *baseline gasoline* - gasoline for a given refiner whose properties are nominally representative of all the U.S. gasoline sold during 1990 as defined by the Clean Air Act Amendments of 1990.

3.2.8 *California Phase 2 Reformulated Gasoline (CaRFG2)* - a gasoline or gasoline-oxygenate blend that meets the specifications and emission reduction requirements established by the California Air Resources Board, in effect from 1996 through 2003.

3.2.9 *California Phase 3 Reformulated Gasoline (CaRFG3)* - a gasoline or gasoline-oxygenate blend that meets the specifications and emission reduction requirements established by the California Air Resources Board, effective December 31, 2003.

3.2.10 *cap limit* - for California Phase 3 Reformulated Gasoline (CaRFG3), an absolute limit (maximum or minimum) which shall be met by each gallon of gasoline.

3.2.11 *Complex Model* - a set of specifications and equations developed by the EPA that predict volatile organic compound, oxides of nitrogen, and toxic air pollutant reductions based on the following parameters: aromatics, benzene, olefins, sulfur, oxygenate type and content, percent evaporated at 200°F, percent evaporated at 300°F, and vapor pressure.

3.2.12 *conventional gasoline* - gasoline which does not meet the requirements of reformulated gasoline or is not intended for sale in a federal RFG area.

3.2.13 *covered area* - a geographic area in which only reformulated gasoline shall be sold or dispensed to ultimate consumers.

3.2.14 *deposit control additive* - material added to gasoline to prevent or remove deposits in the entire engine intake system.

3.2.15 *E200* - the volume percent gasoline evaporated at 200°F during distillation according to Test Method [D86](#).

3.2.16 *E300* - the volume percent gasoline evaporated at 300°F during distillation according to Test Method [D86](#).

3.2.17 *flat limit* - for California Phase 3 Reformulated Gasoline (CaRFG3), a limit for a fuel parameter that applies to each batch of reformulated gasoline; analogous to the federal per gallon standard.

3.2.18 *Mobile Source Air Toxics (MSAT)* - Air Toxics emitted by motor vehicles and other moving sources. Air Toxics, also known as Hazardous Air Pollutants, include benzene, and other chemical compounds such as 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, and naphthalene. MSAT standards have been implemented in two phases - MSAT1 became effective beginning in January 1, 2002; MSAT2 became effective beginning January 1, 2011.

3.2.19 NO_x - oxides of nitrogen emitted by automotive vehicles.

3.2.20 *opt-in* - a provision of the Clean Air Act Amendments allowing a reas other than those mandated to request the EPA to require the use of reformulated gasoline.

3.2.21 *opt-out* - a provision allowing areas which had previously opted into the federal reformulated gasoline program to be removed from the program.

3.2.22 *per gallon maximum* - the highest value that a reformulated gasoline parameter shall have in any batch when averaging; similar to the California Reformulated Gasoline (CaRFG) maximum cap.

3.2.23 *per gallon minimum* - the lowest value that a reformulated gasoline parameter shall have in any batch when averaging; similar to the California Reformulated Gasoline (CaRFG) minimum cap.

3.2.24 *per gallon standard* - a limit for a gasoline parameter that shall be met for each batch of gasoline during the reporting period; similar to the California Reformulated Gasoline (CaRFG) flat limit.

3.2.25 *Phase I RFG (Complex Model)* - a gasoline-oxygenate blend that meets the specifications and emission reduction requirements established by the U.S. EPA, required January 1, 1998. Could be used beginning January 1, 1995.

3.2.26 *Phase II RFG (Complex Model)* - a gasoline-oxygenate blend that meets the specifications and emission reduction requirements established by the U.S. EPA, required January 1, 2000.

3.2.27 *Predictive Model* - a set of equations developed by CARB which predict the change in exhaust hydrocarbon emissions, exhaust emissions of oxides of nitrogen, and the combined exhaust emissions of four toxic air contaminants (1,3-butadiene, benzene, formaldehyde and acetaldehyde). Under CaRFG3, the model was expanded to include an evaporative emissions element and CO credit mechanism.

3.2.28 *reformulated gasoline (RFG)* - a gasoline or gasoline-oxygenate blend certified to meet the specifications and emission reduction requirements established by the Clean Air Act Amendments of 1990, (as amended by the Energy Policy Act of 2005), required for use in automotive vehicles in areas that have been designated as extreme or severe ozone non-attainment areas and those eligible areas which opt to require reformulated gasoline.

3.2.29 *reformulated gasoline blendstock for oxygenate blending (RBOB)* - a hydrocarbon product which, when blended with an oxygenate, meets the definition of reformulated gasoline, and to which the oxygenate is added other than by a refiner or importer.

3.2.30 *renewable fuel standard (RFS)* - Percentage standards for cellulosic biofuel, biomass-based diesel, advanced biofuel and renewable fuel mandated to be used on an annual average basis in gasoline and diesel fuel under Section 211(o) of the Clean Air Act, as amended by the Energy Independence and Security Act of 2007 (EISA).

3.2.31 *Renewable Identification Number (RIN)* - a 38-character numeric code required by EPA under the RFS program and generally assigned to every gallon batch of renewable fuel produced or imported. Refiners and importers obligated to meet the renewable fuel standards must acquire sufficient RINs on an annual basis to demonstrate compliance with their renewable volume obligations for each of the four categories of renewable fuel.

3.2.32 *Reid vapor pressure (RVP)* - the U.S. EPA's designation for gasoline vapor pressure and other volatile products when determined by use of the sampling methodologies

specified in 40 CFR 80.8 and the testing methodology specified at 40 CFR 80.46(c).

3.2.33 *Simple Model* - a set of specifications and equations developed by the EPA that predict volatile organic compound and toxic air pollutant reductions from reformulated gasoline based upon the following fuel parameters: aromatics, benzene and oxygen contents, and vapor pressure; the Simple Model expired 12/31/97 and is no longer used.

3.2.34 *Statutory Baseline* - A set of fuel properties, nominally representative of US gasoline in 1990, used to evaluate emissions improvements of reformulated gasolines.

3.2.35 *Tier 2/Sulfur Content Standards* - Gasoline sulfur content standards for refiners and importers established by the U.S. Environmental Protection Agency. These standards apply to all reformulated gasoline, reformulated gasoline blendstock for oxygenate blending (RBOB), and conventional gasoline beginning with the January 1, 2004 averaging period.

3.2.36 *Tier 3/Sulfur Content Standards* - Gasoline sulfur content standards for refiners and importers established by the U.S. Environmental Protection Agency. These standards apply to all reformulated gasoline, reformulated gasoline blendstock for oxygenate blending (RBOB), conventional gasoline blendstock for oxygenate blending (CBOB), and conventional gasoline beginning with the January 1, 2017 averaging period.

3.2.37 *toxics* - In federal regulations, the sum of five toxic air pollutants (acetaldehyde, benzene, 1,3-butadiene, formaldehyde and polycyclic organic matter) emitted by automotive vehicles; California regulations apply to the sum of the first four only.

3.2.38 *VOC* - volatile organic compounds consisting of non-methane, non-ethane hydrocarbons and oxygenated hydrocarbons emitted by automotive vehicles.

3.2.39 *VOC Control Region 1* - a designation assigned by the EPA to roughly the southern half of the 48 contiguous United States, sometimes referred to as Region B (See Figure 1).

3.2.40 *VOC Control Region 2* - a designation assigned by the EPA to roughly the northern half of the 48 contiguous United States; sometimes referred to as Region C (See Figure 1).

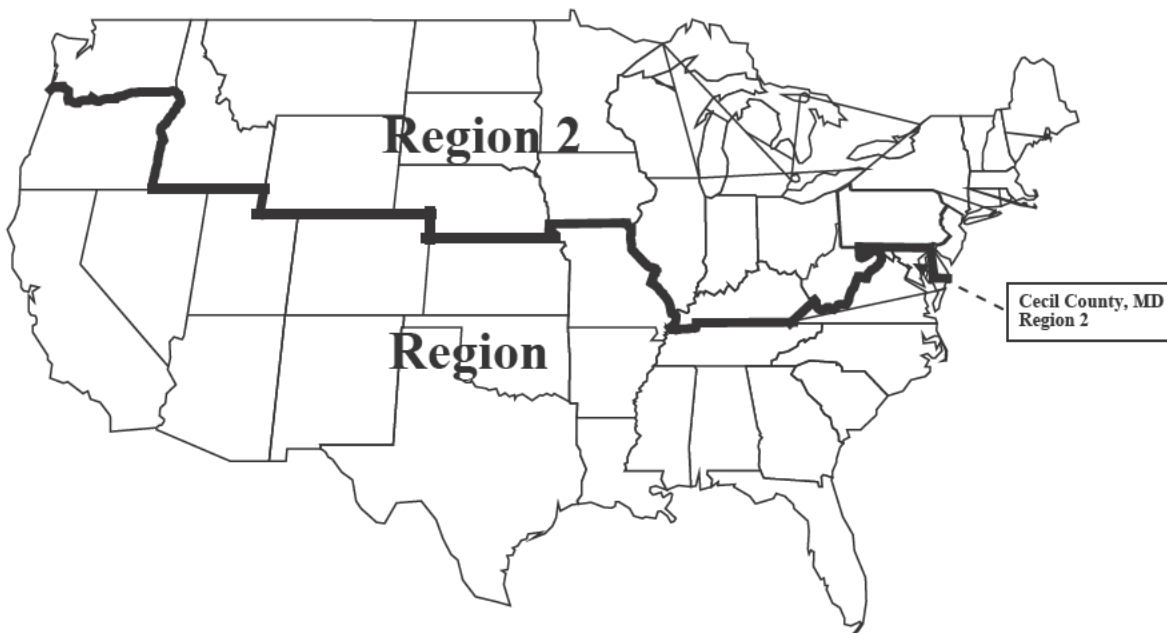
4. Reformulated Gasoline and Renewable Fuel Standard Requirements

4.1 REFORMULATED GASOLINE

4.1 Reformulated gasoline (federal) certified under Phase II of the Complex Model shall conform to the requirements in Table 1. Compliance with federal Phase II performance standards began January 1, 2000. Currently, Federal RFG summertime VOC requirements are met primarily through RVP control. Compliance with the NOx and Toxics performance standards of RFG are met as a result of compliance with EPA gasoline sulfur and MSAT2 benzene standards. (See Section 4.2., "Federal Reformulated Gasoline and the Renewable Fuel Standard" and Section 5, "EPA Gasoline Sulfur Standards" for additional information.)

4.1.1 Starting December 31, 2003, all gasoline sold in California is required to comply with CARB Phase 3 Reformulated Gasoline (CaRFG3) standards. Refer to Table 6 for a list of the CaRFG3 limits. Refer to Section 4.3 for a description of the CaRFG3 standards. Refer to Section 6 for appropriate test methods.

FIGURE 1 U.S. EPA VOC CONTROL REGIONS



4.2 FEDERAL REFORMULATED GASOLINE AND THE RENEWABLE FUEL STANDARD

4.2.1 General requirements (under the 1990 Clean Air Act Amendments as amended by the Energy Policy Act of 2005) for Federal Reformulated Gasoline are a maximum 1.0 percent by volume benzene content, limits on heavy metals, and shall not cause an increase in emissions of oxides of nitrogen. A requirement for deposit control additives in all gasolines was promulgated in 1994 and became effective January 1, 1995 (59 FR 54678, November 1, 1994). Certification standards for these additives were promulgated in 1996 and became effective on July 1, 1997 for gasoline blenders and distributors and on August 1, 1997 for gasoline retailers (61 FR 35310, July 5, 1996).

4.2.1.1 On August 8, 2005, the President signed into law the Energy Policy Act of 2005 (P.L. 109-58). This legislation made significant revisions to the Federal RFG program, and established a Renewable Fuel Standard (RFS) mandating the use of 4 billion gallons of renewable fuels in the U.S. starting in 2006, increasing to 7.5 billion gallons by the year 2012. Other key provisions of the Energy Policy Act of 2005 (EPACT 2005) included elimination of the minimum 2.0 weight percent oxygen requirement in RFG, establishment of a credits trading program, consolidation of VOC Control Regions, establishment of small refiner provisions, modifications to the mobile source air toxics program and baselines, commingling of compliant RFG fuels, and other fuel related provisions.

4.2.1.2 In response to EPACT 2005, EPA conducted a rule-making to eliminate the minimum oxygen content requirement for RFG both nationally and in California. The rule eliminating the oxygen content requirement for Federal RFG areas in California became effective April 24, 2006. The rule eliminating the oxygen requirement for all other RFG areas became effective May 5, 2006.

4.2.1.3 For 2006, EPA adopted the default renewable fuel standard set forth in EPACT 2005. The final rule establishing the complete RFS (RFS1) program for 2007 and beyond became effective September 1, 2007. The Rule established the process for EPA to use in setting annual renewable fuel standards through 2012, defined the responsibilities of refiners and other fuel producers and importers, established a credit trading system and set forth record-keeping and reporting requirements. Under the RFS1 regulations, any party that produces or imports gasoline for use in the U.S. is considered an obligated party and is required to meet the annual renewable fuel standard through the purchase of renewable identification numbers (RINs). Qualifying small refiners and small refineries were exempt from meeting the renewable fuel requirements through 2010. Gasoline producers located in Hawaii and Alaska, and noncontiguous U.S. territories were exempt from the RFS1 program requirements - however these states and territories were allowed to opt into the program. Hawaii opted into the program as of January 1, 2008.

4.2.1.4 The Energy Independence and Security Act of 2007 (P.L. 110-140), enacted on December 19, 2007, significantly expanded and increased the RFS program established under

TABLE 1 EPA COMPLEX MODEL STANDARDS FOR FEDERAL RFG

Emissions Reductions & Properties	Per-Gallon	Phase II Standards (2000+)	
		Average	
		Average Limit	Per-Gallon Limit
VOC Reduction, %^A			
VOC-Control Region 1, minimum	27.5	29.0	25.0 ^C
Adjusted VOC gasoline designated for VOC-Control Region 2, min. ^B	23.9	25.4	21.4 ^C
All other gasoline designated for VOC-Control Region 2, min.	25.9	27.4	23.4 ^C
NO_x Reduction, %			
VOC control period, min.	5.5	6.8	N/A
Non-VOC control period, min.	0	1.5	N/A
Toxics Reduction, %, min.	20.0	21.5	N/A
Benzene, volume %, max.	1.00	0.95	1.30

^A VOC reductions apply to VOC control period only. In addition, under the Complex Model, RFG Covered Areas are subject, during VOC control periods, to reduction requirements as well as Federal Phase II volatility standards.

^B Under 40 CFR § 80.41, EPA adjusted the volatile organic compound (VOC) performance standard under Phase II of the reformulated gasoline (RFG) program for gasoline containing 10 to 15 % by volume ethanol, or RBOB intended for blending with 10 to 15 % by volume ethanol intended for use in the Chicago and Milwaukee RFG areas. In order for "adjusted VOC gasoline" to qualify for the regulatory treatment specified in § 80.41(e) and (f), reformulated gasoline must contain denatured, anhydrous ethanol. The concentration of the ethanol, excluding denaturant, of the finished RFG must be at least 9% and no more than 15 % by volume of the gasoline.

^C Under Phase II of the complex model, the minimum per-gallon VOC emissions performance reduction standards are 25.0% and 23.4% for RFG used in VOC Control Regions 1 and 2 respectively. As a matter of enforcement discretion, EPA is recognizing an enforcement tolerance of 2% for these VOC emissions performance standards in the case of gasoline found at locations downstream of the refinery level. Beginning with the year 2000, EPA considers gasoline downstream of the refinery to have met the applicable VOC emissions performance standard if the emissions performance is 23.0% or 21.4% used in VOC Control Regions 1 and 2, respectively.

EPACT 2005. Section 202 of the Energy Independence and Security Act of 2007 (EISA) required the use of 9.0 billion gallons of renewable fuel in 2008, increasing to 36 billion gallons by 2022. EISA also established an annual volume requirements for four categories of renewable fuel – cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. In 2022, 21 billion gallons of the total renewable fuels requirement must be obtained from cellulosic biofuel and other advanced biofuels (including cellulosic biofuel and biomass-based diesel), and 16 billion gallons of the advanced biofuels requirement must be cellulosic biofuel. To qualify under any of these four categories, a renewable fuel must meet a certain lifecycle greenhouse gas emission threshold, unless the fuel is produced in a facility that had commenced construction prior to enactment of the legislation or, for facilities fired by natural gas, biomass or a combination thereof, by December 31, 2009. **Table 2A** shows the applicable volumes of total renewable fuels required under EISA. EPA is required to annually project the volume of cellulosic biofuel that will be produced, and establish RFS standards for cellulosic biofuel for that year based on the projected level if it is less than the volume set forth in the statute. If EPA reduces the cellulosic biofuel volumes, EPA is authorized to also reduce advanced biofuel and total renewable fuel volumes by an equal or lesser amount. EPA is also authorized under EISA to waive any of the statutory volume requirements if it finds that there is inadequate domestic supply, or that compliance with the statutory volume requirements would cause severe economic harm, or severe environmental harm.

4.2.1.5 On March 26, 2010, EPA published a Final Rule, “Changes to Renewable Fuel Standard Program”, commonly referred to as RFS2.² The RFS2 regulations, which took effect on July 1, 2010 specified the volumes of cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that were required to be used in transportation fuel in 2010. **Table 2A**, “Renewable Fuel Requirements for RFS2”, shows the separate renewable fuel volume requirements for RFS2 mandated under EISA. Under section 211(o) of the Clean Air Act, the Environmental Protection Agency is required to set annual percentage standards for each category of renewable fuel for the following year. On August 15, 2013, EPA published in the Federal Register the volume requirements and associated percentage standards that would apply under the RFS2 program in calendar year 2013 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. The cellulosic biofuel volumes and percentage standards were subsequently changed in a final rule published in the Federal Register on December 14, 2015 (80 FR 77420).³ **Table 2B**, shows EPA’s Renewable Fuel Standards for 2014, 2015, 2016, and the biomass-based diesel volume for 2017. See EPA’s Web page at <https://www.epa.gov/renewable-fuel-standard-program/final-renewable-fuel-standards-2014-2015-and-2016-and-biomass-based>.

4.2.1.6 The RFS2 regulations make a number of changes to the RFS program while retaining many elements of the compliance and trading system established under RFS1. The RFS2 regulations

² “Changes to Renewable Fuel Standard Program; Final Rule”, Federal Register, Vol. 75, No. 58, pages 14669–15320, March 26, 2010.

³ Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017; Final Rule”, Federal Register, Vol. 80, No. 239, pages 77420–77518, December 14, 2015.

TABLE 2A Energy Independence and Security Act of 2007 (P.L. 110-140) Renewable Fuel Applicable Volumes for RFS2 (billion gallons)

Year	Cellulosic biofuel requirement	Biomass-based diesel requirement	Advanced biofuel requirement	Total renewable fuel requirement
2009	n/a	0.5	0.6	11.1
2010	0.1	0.65	0.95	12.95
2011	0.25	0.80	1.35	13.95
2012	0.5	1.0	2.0	15.2
2013	1.0	a	2.75	16.55
2014	1.75	a	3.75	18.15
2015	3.0	a	5.5	20.5
2016	4.25	a	7.25	22.25
2017	5.5	a	9.0	24.0
2018	7.0	a	11.0	26.0
2019	8.5	a	13.0	28.0
2020	10.5	a	15.0	30.0
2021	13.5	a	18.0	33.0
2022	16.0	a	21.0	36.0
2023+	b	b	b	b

^a To be determined by EPA through a future rulemaking, but no less than 1.0 billion gallons.

^b To be determined by EPA through a future rulemaking.

TABLE 2B Renewable Fuel Standards For 2014, 2015, and 2016, and Biomass-Based Diesel Volume for 2017^{a, c}

Volume Standards ^b				
Fuel Category	2014	2015	2016	2017
Cellulosic Biofuel (million gallons)	33	123	230	N/A
Biomass-Based Diesel (billion gallons)	1.63	1.73	1.90	2.00 ^c
Advanced Biofuel (billion gallons)	2.67	2.88	3.61	N/A
Total Renewable Fuel (billion gallons)	16.28	16.93	18.11	N/A
Percentage Standards				
Fuel Category	2014	2015	2016	2017
Cellulosic Biofuel	0.019%	0.069%	0.128%	N/A
Biomass-Based Diesel	1.41%	1.49%	1.59%	N/A
Advanced Biofuel	1.51%	1.62%	2.01%	N/A
Total Renewable Fuel	9.19%	9.52%	10.10%	N/A

^a On December 14, 2015, EPA published in the Federal Register the volume requirements and associated percentage standards that would apply under the RFS2 program in calendar year 2014, 2015, and 2016, and the biomass-based diesel volume for 2017, for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel.

^b All volumes are ethanol-equivalent, except for biomass-based diesel which is actual.

^c On December 14, 2015, EPA published a final rule in the Federal Register establishing an applicable volume of 2.00 billion gallons for biomass-based diesel (BBD) for 2017.

require, with certain exceptions applicable to existing facilities, that each of the mandated volumes of renewable fuels achieve certain minimum thresholds of GHG emission performance and that all renewable fuel be made from feedstocks that meet the definition of renewable biomass. The RFS2 regulations also require that diesel producers and importers, along with gasoline producers and importers, are considered obligated parties. For RFS2, EPA has established an Electronic EPModerated Transaction System (EMTS) to track RIN transactions.

4.2.2 EPA established RFG requirements through rules published in the Federal Register. The EPA Office of Transportation and Air Quality publishes notices from the Federal Register on the following internet site, <http://iaspub.epa.gov/otaqpub/pubsearch.jsp>. The RFG regulations are codified in the Code of Federal Regulations at 40 CFR Part 80, Subpart D.

4.2.3 RFG covered areas include those areas identified under the Clean Air Act Amendments of 1990, ozone non-attainment areas that are reclassified to severe, and opt-in areas. A list of areas required to use reformulated gasoline is published on EPA's web page at <http://www.epa.gov/otaq/fuels/gasoline-fuels/rfg/areas.htm>. Contact the EPA for the most current list of covered areas.

4.2.4 All areas that chose or were required to use RFG after the year 2000 were required to implement the more stringent Phase II standards. Areas that chose to use RFG in their air quality plans and did not opt-out by December 31, 1997, were required to participate in Phase II RFG until December 31, 1999.⁴

4.2.5 Table 1 shows Phase II Complex Model standards. There are both performance standards (VOCs, NO_x , toxics) and content standards (oxygen, benzene). The standards are more stringent if the refiner elects to meet them on an averaging, rather than per-gallon basis.

4.2.6 The complex model is used to calculate NO_x , toxics, and VOC emissions reductions for reformulated gasoline. For calculating emissions reductions from 1998 on, the baseline gasoline shall be set equal to the Clean Air Act statutory baseline for the summer (VOC control period) or EPA specifications for winter (non-VOC control period) baseline gasolines (Table 3). Beginning January 1, 2007 the NO_x emissions standard no longer applied except as provided in 40 CFR 80.41(e)(2)(ii) and 40 CFR 80.41(f)(2)(ii).⁵ Beginning January 1, 2011 for refiners, or January 15, 2015 for small refiners approved under 40 CFR 80.1340, the toxic air pollutant emissions performance reduction and benzene content specified at 40 CFR 80.41(e)(1) or 40 CFR 80.41(f)(1) applies to RFG that is not subject to the MSAT2 standards.⁶

⁴ EPA Final Rule on Transitional and General Opt-Out Procedures for Phase II Reformulated Gasoline, Federal Register, Vol. 62, October 20, 1997, p. 54552.

⁵ For a refiner subject to the small refiner gasoline sulfur standards at 40 CFR 80.240, the NO_x emissions standard specified at 40 CFR 80.41(e)(1) and 40 CFR 80.41(f)(1) no longer applied beginning January 1, 2008. For a refiner subject to the gasoline sulfur standards at 40 CFR 80.240 that received an extension of its small refiner gasoline sulfur standards under 40 CFR 80.553, the NO_x emissions standard specified at 40 CFR 80.41(e)(1) and 40 CFR 80.41(f)(1) no longer applied beginning January 1, 2011.

⁶ See 40 CFR 80.41(e)(3)(i), 40 CFR 80.41(e)(3)(ii), 40 CFR 80.41(f)(3)(i) and 40 CFR 80.41(f)(3)(ii).

TABLE 3 EPA BASELINE FUEL COMPOSITIONS

Fuel Property	VOC control period	Non-VOC control period
Oxygen, mass %	0.0	0.0
Sulfur, ppm, (m/m)	339	338
Vapor Pressure (RVP), kPa (psi)	60.0 (8.7)	79.3 (11.5) ^A
E200, vol. %	41.0	50.0
E300, vol. %	83.0	83.0
Benzene, vol%	1.53	1.64
Aromatics, vol. %	32.0	26.4
Olefins, vol. %	9.2	11.9

^A 60 kPa (8.7 psi) is used for non-VOC control period calculations.

4.2.7 The complex model is used to calculate NO_x and exhaust toxics emissions for conventional gasoline (to meet anti-dumping requirements). Refiners' baseline volumes, properties and emissions performance are used to determine refiners' emission requirements. Conventional gasoline anti-dumping requirements are at 40 CFR Subpart E. Beginning January 1, 2007 the NO_x emissions standard no longer applied except as provided in 40 CFR 80.101(c)(3)(ii).⁷ Beginning January 1, 2011 for refiners, or January 15, 2015 for small refiners approved under 40 CFR 80.1340, the exhaust toxics emission standard specified in 40 CFR 80.101(b)(3)(i) applies to conventional gasoline that is not subject to the MSAT2 standards.⁸

4.2.8 The EPA MSAT2 required that refiners beginning in 2011, and small refiners beginning in 2015 must meet an annual average gasoline benzene content standard of 0.62 volume % or less on all their gasoline, both reformulated and conventional.⁹ The rule includes a nationwide averaging, banking, and trading program, and credits may be used to meet the 0.62 volume % standard. Gasoline sold in California is not covered since California has already implemented more stringent standards. In addition to the 0.62 volume % standard, refiners must also meet a maximum average benzene standard of 1.30 volume % beginning on July 1, 2012 (July 1, 2016 for approved small refiners). A refinery's or importer's maximum average gasoline benzene concentration in any averaging period may not exceed 1.30 volume %, and credits may not be used to meet the 1.30 volume % standard.

4.2.10 The Complex Model is comprised of seven exhaust emissions equations (for VOCs, NO_x , and five toxics: benzene, 1,3-butadiene, formaldehyde, acetaldehyde and polycyclic organic matter (POM)). Exhaust emissions are expressed as the sum of

⁷ For a refiner subject to the small refiner gasoline sulfur standards at 40 CFR 80.240, the NO_x emissions standard specified at 40 CFR 80.101(b)(3)(i) no longer applied beginning January 1, 2008. For a refiner subject to the gasoline sulfur standards at 40 CFR 80.240 that received an extension of its small refiner gasoline sulfur standards under 40 CFR 80.553, the NO_x emissions standard specified at 40 CFR 80.101(b)(3)(i) no longer apply beginning January 1, 2011.

⁸ See 40 CFR 80.101(4)(i) and 40 CFR 80.101(4)(ii).

⁹ MSAT2 benzene standard is specified at 40 CFR.1280 pursuant to the provisions of 40 CFR 80.1235.

exponential functions of gasoline properties for two types of vehicles, normal and high emitters. The model also comprises four non-exhaust emission equations for VOCs (diurnal, hot soak, running loss and refueling emissions) and four corresponding non-exhaust emission equations for benzene. Non-exhaust VOC emissions are a function of vapor pressure (RVP) and $(RVP)^{1.2}$. Non-exhaust benzene emissions are a function of $[\text{benzene} \times \text{non-exhaust VOCs}] \times [a + b (\text{MTBE}) + c (\text{RVP})]$. The equations for exhaust formaldehyde and acetaldehyde and for non-exhaust benzene are oxygenate-specific.

4.2.11 For VOC control period gasoline, the full set of equations applies. For non-VOC control period gasoline, non-exhaust emissions are set equal to zero. There are separate versions of the non-exhaust equations for EPA Control Regions 1 and 2.

4.2.12 Table 4 summarizes the terms in the exhaust and non-exhaust equations.

4.2.13 The Complex Model shall be used over the ranges for gasoline properties shown in Table 5. However, within these ranges there are limits for certain gasoline properties: E200, E300, and aromatics for the VOC exhaust equation and sulfur, aromatics, and olefins for the NO_x equation. Below and above these ranges the Complex Model extrapolates, either using the value of the derivative (i.e., the slope, in the case of a straight line) of the equation at the limit or making a flat line extension.¹⁰ The Complex Model standards applicable to conventional gasoline require that annual averages of each complex model parameter shall not be greater than the model valid range limits or the refiner or importer's annual 1990 baseline for that parameter, whichever is greater. An individual batch of conventional gasoline may have parameters that exceed the complex model acceptable range limits. EPA regulations provide a procedure for evaluating the emissions performance of conventional gasoline with parameters outside of the complex model valid range limits.¹¹

4.2.14 A spreadsheet of the Complex Model may be obtained from EPA's Office of Transportation and Air Quality web page under "RFG Computer Models" at <http://www.epa.gov/otaq/rfg.htm>. The Complex Model spreadsheet is a tool but is not part of the regulation. The written text of the regulation as printed in the Federal Register (and as modified by subsequent Federal Register notices) shall be used for certification.

4.2.15 The federal regulations allow for augmentation of the exhaust emissions part of the Complex Model by vehicle testing (CFR 40, Part 80, Section 48) if a fuel claims emission reduction

benefits from fuel parameters that are not included in the model or its database, or if the values of the fuel parameters are outside the valid ranges for the model.

TABLE 4 EPA MODEL TERMS INCLUDED IN COMPLEX MODEL

Model Terms	Exhaust			Non-Exhaust	
	VOCs	NO_x	Toxics ^A	VOCs	Benzene
Vapor pressure (RVP)	X	X	X	X	X
(RVP) ²				X	X
(RVP) ³					X
Oxygen	X	X	X		
Aromatics	X	X	X		
(Aromatics) ²		X			
Benzene			X		X
Olefins	X	X	X		
(Olefins) ²		X			
Sulfur	X	X	X		
(Sulfur) ²		X			
E200	X	X	X		
(E200) ²	X				
E300	X	X	X		
(E300) ²	X				
Aromatics x E300	X				
MTBE			X		X
TAME					
ETBE			X		
Ethanol			X		

More complex oxygenates are handled differently; refer to the Federal Register, Vol. 59, No. 132, 2/16/94, pgs. 7817, 7825, and the 7/20/94 Direct Final Rule.

^A Does not include Polycyclic Organic Matter.

TABLE 5 EPA VALID RANGES FOR COMPLEX MODEL

Property	RFG		Conventional	
	Low	High	Low	High
Vapor pressure, kPa (psi)	44.1 (6.4)	69.0 (10.0)	44.1 (6.4)	75.8 (11.0)
Oxygen ^A , mass %	0.0	4.0	0.0	4.0
Aromatics, vol%	0.0 ^B	50.0	0.0 ^B	55.0
Olefins, vol. %	0.0	25.0	0.0	30.0
Benzene, vol. %	0.0	2.0	0.0	4.9
Sulfur, ppm m/m	0.0	500.0	0.0	1,000.0
E200, vol. %	30.0	70.0	30.0	70.0
E300, vol. %	70.0	100.0 ^C	70.0	100.0 ^C

^A Pertains to all oxygenates.

^B If <10 vol. %, set equal to 10 vol. %.

^C If >95 vol. %, set equal to 95 vol. %.

¹⁰In 2011, EPA updated the complex model to account for its decision to allow the introduction into commerce of gasoline-ethanol blended fuels containing greater than 10 volume percent ethanol up to 15 volume percent ethanol (E15) for only model year 2001 and newer light-duty motor vehicles. The Complex Model regulations at 40 CFR 80.45 were modified to specify use in the model equations of a 4.0 weight percent oxygen content for fuels with actual oxygen content greater than 4.0 weight percent and up to 5.8 weight percent. [See "EPA Regulation To Mitigate the Misfueling of Vehicles and Engines With Gasoline Containing Greater Than Ten Volume Percent Ethanol and Modifications to the Reformulated and Conventional Gasoline Programs", Federal Register, Vol. 76, July 25, 2011, p. 44429.]

¹¹EPA Final Rule on Modifications to Standards and Requirements for Reformulated and Conventional Gasoline, Federal Register, Vol. 62, December 31, 1997, p. 68196.

TABLE 6 CARB REFORMULATED GASOLINE REGULATIONS
CaRFG3 Average and Flat Limits with Per Gallon Maximums and Minimums

Regulated Property	CARB Phase 3 (December 31, 2003 +)		
	Flat Limit	Averaging Limit	Max. Per Gallon Cap
Aromatics, max, vol. %	25.0	22.0	35.0
Benzene, max, vol. %	0.80	0.70	1.10
Olefins, max, vol. %	6.0	4.0	10.0
Oxygen, mass %	1.8 - 2.2	Not Applicable	1.8 - 3.5 ^A winter areas 0 - 3.5 ^A
Vapor Pressure, max, kPa (psi) during the RVP Control Period	48.3 or 47.6 (7.00 or 6.90 w/evap PM) ^B	Not Applicable	44.1-49.6 (6.40-7.20)
Distillation Temperature, max, °C (°F), at % evaporated 50 vol. %	213	203	220
90 vol. %	305	295	330
Sulfur, max, ppm (m/m)	20	15	20
MTBE and oxygenates other than ethanol, vol. %	Prohibited as provided in Section 2262.6 ^C	Not Applicable	Prohibited as provided in Section 2262.6 ^C

^A If the gasoline contains more than 3.5% by weight oxygen but no more than 10 volume % ethanol, the maximum oxygen content cap is 3.7% by weight.

^B The 6.90 psi flat limit applies only when a producer or importer is using the evaporative emissions model element of the CaRFG Phase 3 Predictive Model, in which case all predictions for evaporative emissions increases or decreases made using the evaporative emissions model are made relative to 6.90 psi and the gasoline may not exceed the maximum RVP cap limit of 7.2 psi. Where the evaporative emissions model element of the CaRFG Phase 3 Predictive Model is not used, the RVP of gasoline sold or supplied from the production or import facility may not exceed 7.0 psi. The 6.90 psi flat limit applies when a producer or importer is using the CaRFG Phase 3 Predictive Model to certify a final blend not containing ethanol. Otherwise, the 7.00 limit applies.

^C Starting December 31, 2003, no person shall use MTBE, in neat form, in the production of California gasoline; or a blending component that contains greater than 0.60 volume percent MTBE when supplied to its California production facility in the production of California gasoline. MTBE concentrations currently may not exceed 0.05 volume percent. In addition, total oxygenates, other than ethanol and MTBE, may not exceed 0.06 weight percent. The California Reformulated Gasoline Phase 3 Amendments, Title 13, California Code of Regulations, Section 2262.6.

4.2.16 Except for some fuel specific certifications, the fuel shall contain a deposit control additive to minimize deposits in fuel injectors and on intake valves. The additive shall comply with EPA 40 CFR 80 Regulation of Fuel and Fuel Additives: Deposit Control Gasoline Additives. The regulations require that the additive limit Port Fuel Injector (PFI) performance degradation to a maximum flow loss of 5% in any injector and limit the amount of intake valve deposit, averaged over all valves, to less than 100 mg after 10,000 miles of testing. On March 3, 2014, EPA issued a Notice of Final Rulemaking: "Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuels Standards". Under these regulations, EPA will accept alternative test data as demonstration of compliance with EPA's intake valve deposit (IVD) and fuel injector deposit (FID) control requirements that are based on the testing requirements of the industry-based TOP TIER™ Detergent Gasoline deposit control program at the time of the Rule's promulgation.

4.3 CALIFORNIA PHASE 3 REFORMULATED GASOLINE (CARFG3)

4.3.1 The California Air Resources Board (CARB) adopted California Phase 3 Reformulated Gasoline Regulations (CaRFG3) in a hearing on December 9, 1999 with a compliance date beginning December 31, 2002. In a hearing on July 25, 2002, the compliance date was postponed until December 31, 2003. The CaRFG3

regulations made the following changes to the CaRFG2 regulations: prohibited the use of methyl tertiary-butyl ether (MTBE) and other oxygenates other than ethanol which have not been approved under a Multimedia Analysis in California gasoline starting December 31, 2003, established a new Phase 3 Predictive Model that includes a new evaporative emissions element and CO credit mechanism, and made amendments to other provisions of the CaRFG2 regulations.¹² CaRFG3 regulations include specifications for the following gasoline properties: aromatic hydrocarbon, benzene, olefin, oxygen, sulfur, lead, phosphorus, and manganese contents, as well as distillation temperatures for T50 and T90, vapor pressure control period by air basin, and final formulation to include model and amount of deposit control additives. CaRFG3 also provides a California Predictive Model, which allows a gasoline producer to establish specifications for an alternative gasoline formulation in lieu of meeting the numerical limits for eight fuel properties published in the regulation. Table 6 summarizes CaRFG3 standards.

4.3.2 CARB adopted Follow-Up Amendments to the CaRFG3 Regulations in a hearing on November 16, 2000.

¹² As of the date of publication of this report, ethanol is the only oxygenate which has been approved. Users of this document can inquire with the California Air Resources Board about the approval status of other oxygenates.

4.3.3 General requirements for CaRFG, including deposit control additives and the elimination of lead, were implemented in 1992. Prohibition of manganese and the limitation of the phosphorus content in California unleaded gasoline occurred in 1977. The regulations appear in the California Code of Regulations, CCR Title 13, sections 2250 - 2272.

4.3.4 CARB adopted amendments to the Gasoline Deposit Control Additive Regulation (Section 2257, Title 13, California Code of Regulations) in a hearing on September 24, 1998. The amendments became effective on July 16, 1999. Under the revised regulation, CARB requires that a gasoline formulation (i) must meet an intake valve performance standard of 50 milligrams per valve averaged across all four intake valves, (ii) does not result in a flow loss of more than five percent for any fuel injector, and (iii) requires a new performance standard that combustion chamber deposits not exceed 1300 milligrams total deposit weight, when averaged over all four combustion chambers, or, does not result in more than 140 percent total deposit weight from all four combustion chambers, relative to the gasoline formulation containing no additive.

4.3.5 The CaRFG specifications address eight different fuel properties. The CaRFG regulations, which overall are more restrictive than those adopted by the U.S. EPA for federal reformulated gasoline, previously allowed producers the option of meeting flat limits or averaging limits but now requires producers to use the California Predictive Model to certify California reformulated gasoline or use the vehicle emissions testing option. CaRFG regulations also contain caps, which are absolute and shall be met by each gallon of California reformulated gasoline. Under 40 CFR 80.81, "Enforcement Exemptions for California Gasoline", U.S. EPA exempts refiners, importers, and blenders of gasoline subject to the state of California's Phase 3 reformulated gasoline regulations from certain enforcement provisions in the federal reformulated gasoline regulations such as recordkeeping and reporting, and certain sampling and testing requirements.

4.3.6 CARB established a primary statewide range for the oxygen content of CaRFG of 1.8 - 2.2 mass% (flat limit requirement). Alternately, producers may use the California Predictive Model (see 4.3.8) to sell CaRFG with a no oxygen content between 0 and 3.5 mass%. During the winter months, CaRFG sold or supplied in the South Coast Area (which includes the counties of Los Angeles, Orange, Riverside, San Bernardino and Ventura) and Imperial County is required to meet a minimum of 1.8 mass%. Under the Energy Policy Act of 2005, EPA issued a rule eliminating the minimum oxygen content requirement for Federal RFG areas in California that prohibited the sale of gasoline containing less than 2.0 mass% oxygen content (1.5% averaging minimum). The Rule became effective April 24, 2006.

4.3.7 CARB established a primary statewide limit for the vapor pressure of CaRFG of 48.3 kPa (7.00 psi) during the summer control season (flat limit requirement). Alternately, producers may use the California Predictive Model (see 4.3.8) to sell CaRFG with a vapor pressure up to 49.6 kPa (7.20 psi). [Table 7](#) lists the air basins, the regulatory control periods, and the regulatory control periods for gasoline producers and importers.

4.3.8 Producers in California can use the California Predictive Model to establish specifications for an alternative gasoline formulation in lieu of meeting the CaRFG specifications. Through the use of the Predictive Model, producers shall show that an alternative formulation would result in emissions reductions equivalent to or better than a fuel meeting the CaRFG3 specifications.

4.3.9 The California Predictive Model is a set of equations which determine the change in exhaust hydrocarbon emissions, exhaust emissions of oxides of nitrogen, the combined emissions of four toxic air contaminants (1,3-butadiene, benzene, formaldehyde and acetaldehyde), and includes an evaporative emissions element and CO credit mechanism. [Table 8](#) describes the model terms included in the exhaust predictive model for CaRFG3. [Table 9](#) describes the model terms included in the evaporative predictive model for CaRFG3.

4.3.10 The CaRFG3 regulations also allow for an alternative CaRFG3 formulation if it can be shown through the vehicle testing option (California Procedures for Evaluating Alternative Specifications for Gasoline Using Vehicle Emissions Testing", section 2266, Title 13 California Code of Regulations) that emissions resulting from the use of the alternative formulation are equal to or less than emissions resulting from the use of CaRFG3 Gasoline.

4.4 CALIFORNIA LOW CARBON FUEL STANDARD (LCFS)

4.4.1 On April 23, 2009, CARB approved a Low Carbon Fuel Standard (LCFS) to reduce greenhouse gas emissions from California transportation fuels. The regulation became effective on April 15, 2010.

4.4.2 The LCFS regulation was adopted pursuant to the provisions of Global Warming Solutions Act of 2006 (Assembly Bill 32, Stats. 2006, ch488) which established a comprehensive, multi-year program to reduce greenhouse gas emissions in California. A goal to reduce the carbon intensity of California transportation fuels by at least 10 percent by 2020.

4.4.3 The LCFS requires providers, refiners, importers and blenders to ensure that the fuels they provide for California meet an annual declining standard of carbon intensity. This is determined by summing the greenhouse gas emissions associated with the production, transportation and consumption of a fuel, referred to as the fuel pathway. The LCFS applies to any California transportation fuels sold, supplied, or offered for sale in California, and to any regulated party responsible for a California transportation fuel in a calendar year. The types of fuel that the LCFS applies to include California reformulated gasoline, California diesel fuel, fossil compressed natural gas, biogas CNG or biogas LNG, electricity, compressed or liquefied hydrogen, blends containing hydrogen, blends containing greater than 10 percent ethanol by volume, blends containing biomass-based diesel, denatured fuel ethanol, neat biomass-based diesel, and other liquid or non-liquid fuels.

4.4.4 The LCFS provides an exemption for specific alternative fuels, and for specific applications including aircraft, racing

TABLE 7 CARB REFORMULATED GASOLINE REGULATIONS
RVP Control Periods in California^A

Air Basin	Regulatory Control Period	Regulatory Control Period (Producers & Importers)
South Coast and Ventura County	April 1 - October 31	March 1 - October 31
San Diego	April 1 - October 31	March 1 - October 31
Mojave Desert	April 1 - October 31	March 1 - October 31
Salton Sea	April 1 - October 31	March 1 - October 31
Great Basin Valley	May 1 - September 30	April 1 - September 30
San Francisco Bay Area	May 1 - October 31	April 1 - October 31
San Joaquin Valley	May 1 - October 31	April 1 - October 31
Sacramento Valley	May 1 - October 31	April 1 - October 31
Mountain Counties	May 1 - October 31	April 1 - October 31
Lake Tahoe	May 1 - October 31	April 1 - October 31
North Coast	June 1 - September 30	May 1 - September 30
Lake County	June 1 - September 30	May 1 - September 30
Northeast Plateau	June 1 - September 30	May 1 - September 30
North Central Coast	June 1 - October 31	May 1 - September 30
South Central Coast ex.Ventura Co	June 1 - October 31	May 1 - October 31

^A RVP control periods were amended by CARB on August 27, 1998 and became effective September 21, 1998.

TABLE 8 CARB PHASE 3 CALIFORNIA PREDICTIVE MODEL
Exhaust Terms Included in the CaRFG3 Model

Model Terms	Exhaust			
	Total Hydrocarbons	NO _x	Toxics ^A	CO
Vapor Pressure	X	X	X	X
Oxygen	X	X	X	X
(Oxygen) ²		X		X
Oxygen x T90	X			
Aromatics	X	X	X	X
(Aromatics) ²	X			
Aromatics x T90	X	X		
Aromatics x Oxygen	X			
Benzene			X	
Olefins	X	X	X	X
Sulfur	X	X	X	X
T50	X	X	X	X
(T50) ²	X	X		
T50 x T90				X
T90	X	X	X	X
(T90) ²	X			X
T50 x Aromatics	X			X
T50 x Oxygen	X	X		X
T90 x Olefins	X			X

^A Toxics are potency-weighted.

vehicles, military tactical vehicles, locomotives, and ocean-going vessels. Various administrative requirements became effective on January 1, 2011.

5. EPA Gasoline Sulfur Standards

5.1 EPA Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements.

5.2 On February 10, 2000 EPA published a final rule “Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements”. Gasoline sulfur standards apply to refineries and importers producing reformulated, RBOB, or conventional gasoline. The regulations allow refiners and importers to include oxygenate when calculating sulfur content, provided certain conditions are met. For conventional gasoline, the requirements of 40 CFR §80.101(d)(4)(ii) must be met. For reformulated gasoline, the requirements of §80.69(a) must be met.

5.3 Table 10 summarizes gasoline sulfur content standards for refiners and importers. Refiners and importers must meet a 30 ppm annual average with a refinery gate per-gallon cap of 80 ppm and a downstream per-gallon cap of 95 ppm. The annual average sulfur content standard can be met with the use of credits generated by a refinery whose annual average is less than 30.00 ppm beginning in 2004 and subsequent years. These credits may be used for demonstrating compliance within 5 years of the year of credit generation.

5.4 EPA Tier 3 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements.

TABLE 9 CARB PHASE 3 CALIFORNIA PREDICTIVE MODEL
Evaporative Terms Included in the CaRFG3 Model

Model Terms	Evaporative					
	Hydrocarbons			Benzene		
	Running Loss	Hot Soak	Diurnal	Running Loss	Hot Soak	Diurnal
Vapor Pressure	X	X	X	X	X	X
(Vapor Pressure) ²	X	X		X	X	
Benzene				X	X	X
Benzene x Vapor Pressure				X	X	X
MTBE x Benzene					X	
Ethanol	X	X	X	X	X	X

5.5 EPA published a final rule “Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuels Standards” on April 28, 2014. This rule became effective on June 27, 2014. Similar to the Tier 2 standards, gasoline sulfur standards apply to refiners and importers producing reformulated, RBOB, CBOB or conventional gasoline. The regulations allow a refiner or importer to include oxygenate when calculating sulfur content, provided certain conditions are met. For conventional gasoline, the requirements of 40 CFR § 80.101(d)(4)(ii) must be met. For reformulated gasoline, the requirements of §80.69(a) must be met.

5.6 Table 10 summarizes gasoline sulfur content standards for refiners and importers. The regulation requires that effective January 1, 2017 regulated parties meet a 10 ppm annual average. The regulation retains the Tier 2 refinery gate per-gallon cap of 80 ppm and the downstream enforcement standard per-gallon cap of 95 ppm maximum. The annual average sulfur content standard can be met with the use of credits. Credits may be generated relative to the 30 ppm Tier 2 annual sulfur content standard prior to January 1, 2017, and relative to the 10 ppm Tier 3 standard

beginning January 1, 2017. Credits generated before January 1, 2017 will be valid for five years or until December 31, 2019, whichever is earlier - no credits generated relative to the 30 ppm sulfur standard may be used for compliance beginning January 1, 2020. Credits Generated relative to the 10 ppm sulfur standard are valid for use for five years after the year in which they are generated. The Tier 3 final rule also contains special provisions for small refiners and small volume refineries. For small refiners and small volume refineries, the start of the program is delayed until January 1, 2020.

6. Test Methods

6.1 The specified fuel properties shall be determined in accordance with the test methods listed below.

6.2 Performance Based Measurement System (PBMS). EPA issued PBMS requirements in the Tier 3 final rule for analytical test methods used for demonstrating compliance with EPA fuel standards. These PBMS requirements will become effective on January 1, 2016. Test methods for the fuel property of sulfur in Table 11

TABLE 10 EPA GASOLINE SULFUR STANDARDS FOR REFINERS AND IMPORTERS

Federal Program	Gasoline Sulfur Standards (Tier 2) ^A for the averaging period beginning: January 1, 2007 through December 31, 2016	
	Refinery or Importer Annual Average	30.00 ppm
	Per-Gallon Cap	80 ppm
	Downstream of Refineries and Importers (Per-Gallon Cap)	95 ppm
Federal Program	Gasoline Sulfur Standards (Tier 3) ^B for the averaging period beginning: January 1, 2017 & subsequent years	
	Refinery or Importer Annual Average	10.00 ppm
	Per-Gallon Cap	80 ppm
	Downstream of Refineries and Importers (Per-Gallon Cap)	95 ppm

^A EPA Final Rule, Control of Air Pollution From New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Federal Register: February 10, 2000, Vol.65, FR 6698-6870. (February 10, 2000).

^B EPA Final Rule, Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuels Standards; Federal Register: 79 FR 23413-23886 (April 28, 2014)

TABLE 11 Summary of ASTM, EPA, and CARB Test Methods and EPA Test Tolerances and CARB Reproducibilities for Reformulated Gasoline

PROPERTY	ASTM ^A		EPA		CARB	
	Test Method	Comments/Limitations	Test Method ^B	Test Tolerance ^D	Test Method	Reproducibility of CARB Method
Aromatics	D1319-15	Correct for oxygenate measured by D4815 or D5599 or equivalent	ASTM D5769-10 (except sample chilling requirements in Section 8 are optional) ^C	N/A	D5580-02 (2007)	0.2619(x) ^{0.5} volume %
	D5580-15	None				
	D5769-15	None				
Benzene	D3606-10	Alcohol interferes	D3606-10 with exceptions for methanol and ethanol ^{C,E}	0.21 volume %	D5580-02 (2007)	0.1087(x) ^{0.64} volume %
	D5580-15	None				
	D5769-15	None				
	D5986-96 (2015)	None				
	D6277-07 (2012)	None				
Distillation	D86-15	None	D86-15 ^C	N/A	D86-99a ^{el}	Variable as a function of slope
Olefins	D1159-07 (2012)	None	D1319-13 ^C	N/A	D6550-10 ^F	CARB uses 0.32(x) ^{0.5} where x is between 0.3 and 25 mass % olefin
	D1319-15	Correct for oxygenate measured by D4815 or D5599 or equivalent				
	D6550-15	None				
Oxygen	D4815-15b	None	D5599-00 (2010) ^C	0.3 weight %	D4815-09 (permitted oxygenates only)	For Ethanol: 0.23(x) ^{0.57} mass %
	D5599-15	None				
	D5622-95 (2011)	None				
	D5845-01 (2011)	None				
	D5986-96 (2015)	None			D5986-96 Equiv.:GC/FTIR ^G (permitted oxygenates only)	For MTBE range: 1 to 15 mass % 0.17 (x) ^{0.5} mass% For Ethanol range: 1 to 12 mass % 0.11 (x) ^{0.5} mass % Other oxygenates have other equations
D7754-16	None	D7754-11 Prohibited oxygenates	MTBE reproducibility: 0.5809(x) ^{0.8476} ppm mass (Other oxygenates have other equations)			
Sulfur	D2622-16	Range: 3 mg/kg to 4.6 mass %	D2622-10 ^C	N/A ^H	Equiv.: D4045-96 (modified) Range: 1 to 10 ppm ^G	0.26 (x) ^{0.5} ppm
	D3120-08 (2014)	Range: 3.0 to 1000 mg/kg				
	D4045-15	Range: 0.02 to 10.00 mg/kg				
	D4294-16 ^{el}	Range:17 mg/kg to 4.6 mass %				

(Continued)

TABLE 11 Summary of ASTM, EPA, and CARB Test Methods and EPA Test Tolerances and CARB Reproducibilities for Reformulated Gasoline (Continued)

PROPERTY	ASTM ^A		EPA		CARB	
	Test Method	Comments/Limitations	Test Method ^B	Test Tolerance ^D	Test Method	Reproducibility of CARB Method
Vapor Pressure	D5453-12	Range: 1 to 8000 mg/kg			D5453-93	0.2217(x) ^{0.92} ppm
	D6920-13	Range: 1 to 100 mg/kg			Equiv.: D7039-04 ^G Range: 2 to 100 ppm	0.4761(x) ^{0.500} ppm
	D7039-15a	Range: 3.2 mg/kg to 2822 mg/kg				
	D323-15a	None			D323-58	0.21 psi
	D4953-15	Procedure A = dry bomb Procedure B = Herzog (with A and B correlation equations)			13 CCR Section 2297	0.21 psi
D5191-15	None	D5191-13 except that the following correlation must be used during reporting: RVP psi = (0.956*X)-0.347 RVP kPa = (0.956*X)-2.39 Where: X=total measured vapor pressure in psi or kPa ^C	0.30 psi ^I			
D5482-07(2013)	None					
	D6378-10	None			Equiv.: D6378-08 using the relative bias for CARB ^H . ^I Range: up to 9.50 psi	0.0273 (x + 1.31) psi
Detergency (PFI)	D5500-16	Vehicle evaluation ^J	D5500-94	N/A	D5500-98	N/A
Detergency (IVD)	D5598-01(2012)	Vehicle evaluation ^J	D5598-94	N/A	D5598-95a	N/A
Detergency (CCD)	N/A	N/A	N/A	N/A	Stationary Source Division's Test Method for Evaluating Intake and Combustion Chamber Deposits in Vehicle Engines	N/A

^A For ASTM reproducibility and repeatability refer to most recent version of "Annual Book of ASTM Standards".

^B Test Methods listed in 40 CFR 80.46 effective until December 31, 2015. Performance Based Measurement System requirements listed in 40 CFR 80.47 effective on January 1, 2016.

^C Designated primary test methods listed in 40 CFR 80.46 that are in use prior to October 28, 2013 are exempt from Performance Based Analytical Test Method Approach qualification requirements in 40 CFR 80.47. Any Voluntary Consensus Standards Body (VCSB) or Non-VCSB test method may qualify for use if it meets the qualification requirement in 40 CFR 80.47.

^D EPA test tolerances apply downstream of the refinery, and apply only to those properties governed by downstream minimum or maximum standards.

^E Under EPA's Regulations in 40 CFR 80.46(e), instrument parameters shall be adjusted to ensure complete resolution of the benzene, ethanol, and methanol peaks to overcome possible alcohol interference.

^F For D6550-10, the application range applied by CARB is 0.3 to 25 mass%. The conversion from mass% olefin to volume% olefin is: volume% olefin = (0.857) (mass% olefin).

^G Deemed equivalent by CARB.

^H See Table 10. The downstream standard is 95 ppm maximum.

^I The relative bias for CARB is listed in Note 18 of ASTM D6378-08. For predicting CARB RVPE, use the following equation CARB RVPE = VP4 (37.8°C)1-L container - Relative Bias.

^J EPA regulations at 40 CFR §§80.161(b), 80.163(a)(1)(iii), 80.164(a), 80.165, 80.167(a), 80.176, and 80.177 permit the use of fuel injector and intake valve deposit tests specified in the TOP TIER™ Detergent Gasoline Standard (www.toptiergas.com) as alternatives to D5598 and D5500, respectively.

must meet applicable accuracy and precision criterion as defined for its applicable absolute fuel parameter. Test methods for all other fuel properties in [Table 11](#) must meet accuracy and precision criterion as defined for its applicable method-defined fuel parameter. In addition, test facilities will be required to meet minimal statistical quality control (SQC) requirements for each instrument used in its facility. The PEMS requirements can be found in 40 CFR 80.47. A special provision applies to EPA designated test methods. [See Footnote C in [Table 11](#)].

APPENDIXES

(NONMANDATORY INFORMATION)

X1. SIGNIFICANCE OF SPECIFIED PROPERTIES FOR REFORMULATED SPARK-IGNITION ENGINE FUEL

X1.1 GENERAL

X1.1.1 The characteristics of federal reformulated gasoline, California RFG, and EPA approved state fuel described in this report are legal requirements which are imposed by the U.S. EPA, under the authority of the 1990 Clean Air Act Amendments (CAAA), and the California Air Resources Board's Phase 2 and Phase 3 Reformulated Gasoline Regulations, to lower the exhaust and evaporative emissions from automotive vehicles. Aromatics, benzene, olefins, oxygen/oxygenates, vapor pressure, sulfur and E200/300 percentages (distillation) are controlled variables in the federal Complex Model and the California Predictive Model. The significance of these fuel characteristics is described below.

X1.1.2 Exhaust and evaporative emissions from spark-ignition automotive vehicles are affected by the composition and volatility of the fuel. Hydrocarbon and oxygenated hydrocarbon emissions that escape into the atmosphere are called Volatile Organic Compounds (VOCs). These emissions occur as tank storage losses, refueling losses, or as exhaust emissions or evaporative losses that occur either during vehicle operation or when the vehicle is at rest. Volatile Organic Compounds (VOCs), when emitted into the atmosphere, contribute to the photochemical formation of ozone, a major air quality problem in many urban areas.

X1.1.3 Exhaust and evaporative emissions from spark-ignition automotive vehicles may also contain the regulated air toxics defined in the 1990 CAAA: benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and/or polycyclic organic matter. The amount of these toxics present in automotive emissions can be affected by the composition of the fuel.

X1.1.4 Other fuel characteristics affecting engine operability, which are outside the scope of these reformulated fuel regulatory controls, are found in ASTM [D4814](#), Standard Specification

for Automotive Spark-Ignition Engine Fuel. These operability characteristics are not discussed in this report.

X1.2 AROMATICS

X1.2.1 Aromatic compounds are unsaturated ring-structured compounds controlled by EPA and CARB regulations because they contribute to VOC and toxics inventories.

X1.3 BENZENE

X1.3.1 Benzene is controlled in reformulated gasoline because it is a toxic chemical. A portion of the fuel benzene may pass through the engine unburned, and benzene may be produced in the engine from precursors present in the fuel, adding to the total benzene present in the engine exhaust and evaporative emissions.

X1.4 OLEFINS

X1.4.1 Olefins are chemically reactive unsaturated straight or branched chain hydrocarbons which are controlled variables in the federal Complex Model and the CARB Predictive Model. In the Complex Model, olefins affect exhaust VOC, NO_x and toxics.

X1.5 OXYGEN AND OXYGENATES

X1.5.1 Oxygen may be intentionally introduced into reformulated fuel for spark-ignition engines by the addition of organic, fuel-soluble compounds called oxygenates. These are generally in the form of alcohols or ethers, limited by the Substantially Similar rule and EPA waivers.

X1.5.2 Federal reformulated gasoline no longer contains an oxygenate requirement. EPA repealed the minimum oxygen content requirement for Federal RFG areas in California effective April 24, 2006. EPA repealed the minimum oxygen content requirement for all other RFG areas effective May 5, 2006.

X1.6 VAPOR PRESSURE

X1.6.1 Although vapor pressure limits are regulated by the EPA for summertime non-reformulated (conventional) spark-ignition engine fuel, EPA and CARB regulations have required further reductions in the vapor pressure of reformulated fuels to reduce VOCs.

X1.6.2 Evaporative losses from automotive fuel systems as well as exhaust emissions are reduced with lower vapor pressure fuel. Lowering the vapor pressure of a fuel also reduces fuel evaporative losses of VOCs to the atmosphere during storage and transfer operations.

X1.7 SULFUR

X1.7.1 Sulfur has been shown to cause a loss of catalyst activity in automotive catalytic converters that is essentially reversible, although loss of activity in some catalysts may not be completely reversible under all operating conditions. Sulfur impacts exhaust emission equations (VOC, NO_x) in the federal Complex Model and the California Predictive Model.

X1.8 DISTILLATION TEMPERATURE

X1.8.1 Distillation temperature limits on automotive spark-ignition engine fuel are used to control unburned hydrocarbons (VOCs) in the exhaust. The Complex Model controls the distillation of the fuel by controlling the volume percent evaporated at 200°F and at 300°F, while the CARB Predictive Model uses T_{50} (the temperature, in degrees F, where 50% of the liquid volume of fuel has evaporated) and T_{90} (the temperature, in degrees

F, where 90% of the liquid volume of fuel has evaporated), as measured by ASTM D 86.

X1.9 DETERGENCY

X1.9.1 – Port Fuel Injector Deposits (PFID) - Deposits which form on the metering surfaces of electronic fuel injectors can result in a reduction in fuel flow and disruption of proper air-fuel mixing. This results in an imbalance in the air-fuel ratio across the cylinders and in other combustion inefficiencies which can adversely affect emissions, driveability, and fuel economy. The mechanism of deposit formation is not completely

understood, but may be influenced by port fuel injector design, engine design, the composition of the fuel used, and by driving cycle. Deposit control additives are required to limit PFI deposits. Additives which are capable of adequately limiting PFI deposits are also accepted as adequately controlling throttle body and carburetor deposits in older vehicles.

X1.9.2 Intake Valve Deposits (IVD) - Deposits which form on the stem and tulip areas of intake valves can adversely affect emissions and driveability. The mechanism of deposit formation is not completely understood, but may be influenced by the composition of the fuel used, engine design, and driving cycle. The mechanism by which intake valve deposits impact emissions is also not completely understood. Adsorption and desorption of fuel on the IVD and the thermal insulating properties of the IVD can interfere with proper air-fuel mixing and the maintenance of proper air-fuel ratio across the cylinders. Deposit control additives are therefore required to limit IVD.

X1.9.3 See Section 4.2.15 for a discussion of EPA detergency regulatory requirements.

X2. EPA COVERED AREAS

X2.1 Covered Areas are subject to change. Contact the EPA for the most recent list of covered areas.

EPA RFG COVERED AREAS

Clean Air Act Required Areas

CALIFORNIA

LOS ANGELES-South Coast Air Basin, South East Desert, Ventura, CA

- Los Angeles County, CA
- Ventura County, CA
- Orange County, CA
- San Bernardino County (partial), CA
- Riverside County (partial), CA

SACRAMENTO, CA

- El Dorado County (partial), CA
- Placer County (partial), CA
- Sacramento County, CA
- Solano County (partial), CA
- Sutter County (partial), CA
- Yolo County, CA

SAN JOAQUIN VALLEY, CA

- Fresno County, CA
- Kern County (part), CA
- Kings County, CA
- Madera County, CA
- Merced County, CA
- San Joaquin County, CA
- Stanislaus County, CA
- Tulare County, CA

SAN DIEGO, CA

- San Diego County, CA

CONNECTICUT

HARTFORD-New Haven-Waterbury CT

- Hartford County (partial), CT
- Litchfield County (partial), CT
- Middlesex County (partial), CT
- New London County (partial), CT
- New Haven County (partial), CT
- Tolland County (partial), CT

CHICAGO-Gary-Lake County, IL-Indiana-Wisconsin area

- Cook County, IL
- Du Page County, IL
- Grundy County (partial), IL
- Kane County, IL
- Kendall County (partial), IL
- Lake County, IL
- McHenry County, IL
- Will County, IL
- Lake County, IN
- Porter County, IN

PHILADELPHIA-Wilmington-Trenton- Cecil County, MD area PA-NJ-DE-MD

- New Castle County, DE
- Kent County, DE
- Cecil County, MD
- Burlington County, NJ
- Camden County, NJ
- Cumberland County, NJ
- Gloucester County, NJ
- Mercer County, NJ
- Salem County, NJ
- Bucks County, PA
- Chester County, PA
- Delaware County, PA
- Montgomery County, PA
- Philadelphia County, PA

NEW YORK-Northern New Jersey-Long Island-Connecticut area, NY-NJ-CT

- Fairfield County, CT
- Litchfield County (partial), CT
- New Haven County (partial), CT
- Bergen County, NJ
- Essex County, NJ
- Hudson County, NJ
- Hunterdon County, NJ
- Middlesex County, NJ
- Monmouth County, NJ
- Morris County, NJ
- Ocean County, NJ
- Passaic County, NJ
- Somerset County, NJ
- Sussex County, NJ
- Union County, NJ
- Bronx County, NY
- Kings County, NY
- Nassau County, NY
- New York County, NY
- Orange County, NY
- Putnam, NY
- Queens County, NY
- Richmond County, NY
- Rockland County, NY
- Suffolk County, NY
- Westchester County, NY

DISTRICT OF COLUMBIA

- Washington, DC-MD-VA area
- Entire District of Columbia

MARYLAND

BALTIMORE, MD

- Anne Arundel County, MD
- Baltimore County, MD
- Carroll County, MD
- Harford County, MD
- Howard County, MD
- à e City of Baltimore, MD

Washington, DC-MD-VA area (MD portion)

- Calvert County, MD
- Charles County, MD
- Frederick County, MD
- Montgomery County, MD
- Prince Georges County, MD

VIRGINIA

Washington DC-MD-VA area (VA portion)

- Alexandria, VA
- Arlington County, VA
- Fairfax, VA
- Fairfax County, VA
- Falls Church, VA
- Loudoun County, VA
- Manassas, VA
- Manassas Park, VA
- Prince William County, VA
- Stafford County, VA

TEXAS

HOUSTON-Galveston-Brazoria, TX

- Brazoria County, TX
- Chambers County, TX
- Fort Bend County, TX
- Galveston County, TX
- Harris County, TX
- Liberty County, TX
- Montgomery County, TX
- Waller County, TX

WISCONSIN

MILWAUKEE-Racine, WI

- Kenosha County, WI
- Milwaukee County, WI
- Ozaukee County, WI
- Racine County, WI
- Washington County, WI
- Waukesha County, WI

EPA RFG COVERED AREAS

Opt-In Areas

CONNECTICUT, à e Entire State

- Litchfield County (partial), CT
- Hartford County (partial), CT
- Middlesex County (partial), CT
- New Haven (partial), CT
- New London County (partial), CT
- Tolland County (partial), CT
- Windham County, CT

DELAWARE, à e Entire State

- Sussex nonattainment area**
- Sussex County, DE

ILLINOIS**St. Louis, IL-MO nonattainment area**

- (Illinois portion)
- Jersey County, IL
- Madison County, IL
- Monroe County, IL
- St. Clair County, IL

KENTUCKY**Cincinnati-Hamilton KY-OH area (KY portion)**

- Boone County, KY
- Campbell County, KY
- Kenton County, KY

Louisville, KY-IN area (KY portion)

- Jefferson County, KY
- Bullitt County (partial), KY
- Oldham County (partial), KY

MARYLAND**Kent & Queen Anne's nonattainment area**

- Queen Anne's County, MD
- Kent County, MD

MAINE

- Androscoggin County, ME
- Cumberland County, ME
- Kennebec County, ME
- Knox County, ME
- Lincoln County, ME
- Sagadahoc County, ME
- York County, ME

MISSOURI**St. Louis nonattainment area**

- Franklin County, MO
- Jefferson County, MO
- St. Charles County, MO
- St. Louis County, MO
- St. Louis City, MO

MASSACHUSETTS, à e Entire State**Boston-Lawrence-Worcester (Eastern MA)**

- Barnstable County, MA
- Bristol County, MA
- Dukes County, MA
- Essex County, MA
- Middlesex County, MA
- Nantucket County, MA
- Norfolk County, MA
- Plymouth County, MA
- Suffolk County, MA
- Worcester County, MA

Springfield (Western MA) nonattainment area

- Berkshire County, MA
- Franklin County, MA
- Hampden County, MA
- Hampshire County, MA

NEW HAMPSHIRE**Boston-Lawrence-Worcester, MA-NH nonattainment area (NH portion)**

- Hillsborough County, NH
- Rockingham County, NH
- Merrimack County, NH
- Strafford County, NH

NEW JERSEY, à e Entire State**Allentown-Bethlehem-Easton area (NJ portion)**

- Warren County, NJ

Atlantic City nonattainment area

- Atlantic County, NJ
- Cape May County, NJ

NEW YORK**Essex nonattainment area**

- Dutchess County, NY
- Essex County (partial), NY

RHODE ISLAND, à e Entire State**Providence nonattainment area**

- Bristol County, RI
- Kent County, RI
- Newport County, RI
- Providence County, RI
- Washington County, RI

TEXAS**Dallas-Fort Worth nonattainment area**

- Collin County, TX
- Dallas County, TX
- Denton County, TX
- Tarrant County, TX

VIRGINIA**Richmond, VA nonattainment area**

- Charles City County, VA
- Chesterfield County, VA
- Colonial Heights, VA
- Hanover County, VA
- Henrico County, VA
- Hopewell, VA
- Richmond, VA

Norfolk-Virginia Beach-Newport News area

- Chesapeake, VA
- Hampton, VA
- James City County, VA
- Newport News, VA
- Norfolk, VA
- Poquoson, VA
- Portsmouth, VA
- Suffolk, VA
- Virginia Beach, VA
- Williamsburg, VA
- York County, VA

X3. State Cleaner Burning Gasoline Programs

X3.1 OVERVIEW

X3.1.1 A number of states have adopted EPA approved state fuel programs in their State Implementation plans that are more stringent than the Federal requirements. Most of these programs are low RVP programs. In addition to California, Arizona (Maricopa County and portions of Pinal and Yavapai counties) has adopted cleaner burning gasoline standards. While the Georgia (Atlanta) fuel program was more of a low volatility fuel program, the state retained a more local sulfur averaging requirement with the same federal caps and averages¹³. This report covers federal reformulated gasoline or EPA approved State fuel

¹³EPA issued a final rule on September 1, 2015 (80 FR 52627) that removed the Georgia gasoline program that covered a 45-county Atlanta area from the State's approved SIP. That rule was effective on October 1, 2015. With the removal of the Georgia gasoline program from the SIP, a 13-county Atlanta area is now subject to the 7.8 psi federal volatility requirement. The 13 counties in the Atlanta area are: Cherokee County, Clayton County, Cobb County, Coweta County, DeKalb County, Douglas County, Fayette County, Forsyth County, Fulton County, Gwinnett County, Henry County, Pauldin County and Rockdale County.

cleaner burning gasoline regulations which establish limits on vapor pressure, sulfur, olefins, aromatics, oxygen/oxygenates, and other properties, (and combinations thereof), or have adopted certain provisions of the Federal and/or California reformulated gasoline program. States establishing a lower vapor pressure limit than required by Federal EPA are covered in ASTM D4814, Standard Specification for Automotive Spark-Ignition Engine Fuel.

X3.2 ARIZONA CBG

X3.2.1 The State of Arizona requires that all gasoline sold or offered for sale for use in motor vehicles within the Cleaner-Burning Gasoline (CBG) covered area must meet the requirements of Title 20, Chapter 2, Article 7 of the Arizona Administrative Code. The CBG covered area includes all of Maricopa County and portions of Pinal and Yavapai counties. Additionally, the western half of Pinal County is required to use CBG from May 1 to September 30 of each year. See Arizona Statutes for specific geographical requirements (ARS 49-541 and 41-2121).

X3.2.2 In addition to the other provisions of Article 7, all Arizona CBG must meet the general requirements of Section R20-2-751. (See Table X3.1). Beginning November 1, 2000, a set of wintertime requirements applies. (See Table X3.2). Arizona CBG must

TABLE X3.1 ARIZONA CBG
General Requirements

Fuel Property/Performance Standard	Limits
Sulfur (ppm by weight, max)	500 ¹ (80 ²)
Aromatics (vol. %, max)	50
Olefins (vol. %, max)	25
E200 (vol. %)	70-30
E300 (vol. %)	100-70
Maximum Vapor Pressure	
Oct. 1 - March 31 (psi)	9.0
April (psi)	10.0
May (psi)	9.0
June 1 - Sept. 30 (psi)	7.0
Oxygen and Oxygenates	
Minimum Content	
Nov. 1 - March 31 (vol. %, ethanol)	10
(If A.R.S. § 41-2124(E) petition in effect: 2.7 percent oxygen by weight as approved by the Director.	2.7
April 1 - Oct. 31 (mass %) (min)	0
Maximum Content	The maximum oxygen content shall not exceed 4.0% by weight for fuel ethanol and as specified in A.R.S. §41-2122 for other oxygenates, and shall comply with the requirements of A.R.S. § 41-2123.
Federal Complex Model VOC Emissions Reduction Percentage	
May 1 through Sept. 15 (%)	≥ 27.5
(Federal Complex Model settings: summer, Area Class B, Phase 2)	

Note: Arizona Final Rule: Arizona Administrative Code, Title 20. Commerce, Banking, and Insurance, Chapter 2. Department of Weights and Measures, Article 7, Motor Fuels and Petroleum Products, Supp. 06-3, September 30, 2006.

Notice of Final Rulemaking Title 20. Commerce, Financial Institutions, and Insurance Chapter 2, Department of Weights and Measures, March 12, 2011.

¹ Approved sulfur limit in Arizona State Implementation Plan. Superseded by Federal sulfur limit.

² Federal EPA gasoline sulfur limit.

TABLE X3.2 ARIZONA CBG^A
Wintertime Requirements (November 1-March 31)

Regulated Property	Limits
Sulfur (ppm by weight, max)	80
Aromatics (vol. %, max)	30
Olefins (vol. %, max)	10
90% Distillation Temperature (T90) (°F)	330
50% Distillation Temperature (T50) (°F)	220
Vapor Pressure (psi, max)	9.0
Oxygenate - Ethanol	
Minimum oxygenate content (vol. %, ethanol)	10% ethanol by volume
Maximum oxygen content (mass %, oxygen; shall comply with the requirements of A.R.S. § 41-2123.)	4.0

Note: Arizona Final Rule: Arizona Administrative Code, Title 20. Commerce, Banking, and Insurance, Chapter 2. Department of Weights and Measures, Article 7, Motor Fuels and Petroleum Products, Supp. 06-3, September 30, 2006. Notice of Final Rulemaking Title 20. Commerce, Financial Institutions, and Insurance Chapter 2, Department of Weights and Measures, March 12, 2011.

^A Requirements effective November 1, 2000.

also comply with either of the following fuel reformulation options: “Type 1 gasoline”, which is similar to Federal Phase II RFG, or “Type 2 gasoline” which is similar to CARB Phase 2 gasoline. (See [Table X3.3](#) for “Type 1 gasoline” and [Table X3.4](#) for “Type 2 gasoline”.) For certain parameters, the downstream requirements may be different and the reader is advised to review the applicable state requirements at Section R20-2-751. Further, these tables reflect the limits that have been approved in the SIP. Certain limits in the current Section R20-2-751 may be different due to amendments that have not been submitted to EPA for SIP approval.

X3.2.3 “Type 1 gasoline” means a gasoline that meets the general requirements of R20-2-751 and the standards contained in Table 1 of Article 7 and is certified using the federal complex model. “Type 2 gasoline”, means a gasoline that meets the standards contained in Table 2 of Article 7, or is certified using the

California Predictive Model according to the requirements of R20-2-751(F), G, H, and Column A of Table 2 of Article 7.

X3.2.4 In addition to the other requirements of Article 7, from and after November 1, 2000 through March 31, 2001, and from the period beginning November 1 through March 31 of each subsequent year, all Arizona CBG must meet the wintertime requirements provided in [Table X3.2](#)

X3.3 CLARK COUNTY, NEVADA [CBG PROGRAM NO LONGER IN EFFECT]

X3.3.1 On September 27, 2010 (59090 FR 9/27/10), EPA approved a final rule moving the Nevada clean burning fuel requirements from an active measure to a contingency measure in their State Implementation Plan. This program is no longer in effect and conventional gasoline requirements are now applicable.

TABLE X3.3 ARIZONA CBG
 "Table 1-Type 1 Arizona CBG Standards"

	Non-averaging Option	Averaging Option		
	A	B	C	D
Performance Standard/Fuel Property ^B	Per-Gallon (minimum)	Average	Minimum (per-gallon)	Maximum (per-gallon)
VOC Emission Reduction (%)				
May 1 - Sept. 15	≥ 27.5	≥ 29.0	≥ 25.0	N/A
NO _x Emission Reduction (%)				
May 1 - Sept. 15	≥ 5.5	≥ 6.8	N/A	N/A
NO _x Emission Reduction (%)				
Sept. 16 - Nov. 1 and April 1 - April 30 ^C	≥ 0.0	N/A	N/A	N/A
Oxygen content: ethanol, (% by weight unless otherwise noted)				
Nov. 1-March 31 ^C	N/A	N/A	N/A	N/A
April 1 - Nov. 1	0.0 ^A	N/A	0.0	4.0
Oxygen content: other than ethanol, (% by weight)				
Nov. 1 - March 31 ^C	N/A	N/A	N/A	N/A
April 1 - October 31	0.0	N/A	0.0	As specified in A.R.S. § 41-2122.

Note: Arizona Administrative Code, Title 20. Commerce, Banking, and Insurance, Chapter 2. Department of Weights and Measures, Article 7, Motor Fuels and Petroleum Products, 06-3, September 30, 2006.

Notice of Final Rulemaking Title 20. Commerce, Financial Institutions, and Insurance Chapter 2, Department of Weights and Measures, March 12, 2011.

^A Maximum oxygen content must comply with the EPA oxygenate waiver requirements and with A.R.S § 41-2122.

^B Dates represent compliance dates for service stations and fleet owners for the owner of a motor fuel dispensing site or a fleet vehicle fueling facility.

^C Registered suppliers shall certify all Arizona CBG as Type 2 gasoline meeting the standards in Table 2 for each specified winter season.

TABLE X3.4 ARIZONA CBG
 "Table 2 - Type 2 Arizona CBG Standards"

	Averaging Option		Non-averaging Option	
	A	B	C	
Fuel Property	Maximum Standard (per gallon)	Averaging Standard^A	Flat Standard^A (per gallon maximum)	Units of Standard
Sulfur Content	80	30	40	Parts per million by weight
Olefin Content	10.0	4.0	6.0	% by volume
90% Distillation Temperature (T90)	330	290	300	Degrees Fahrenheit
50% Distillation Temperature (T50)	220	200	210	Degrees Fahrenheit
Aromatic Hydrocarbon Content	30.0	22.0	25.0	% by volume
Oxygen content: fuel ethanol ^B				
Nov. 1- March 31	10% ethanol ^B		10% ethanol ^B	% by vol.
April 1 - October 31		-		
The maximum oxygen content		-	4.0	% by weight
EtOH year round				

Note: Dates represent compliance dates for service stations and fleet owners. Arizona Administrative Code, Title 20. Commerce, Banking, and Insurance, Chapter 2. Department of Weights and Measures, Article 7, Motor Fuels and Petroleum Products, 06-3, September 30, 2006. Notice of Final Rulemaking, Title 20. Commerce, Banking, and Insurance, Chapter 2. Department of Weights and Measures, Article 7, Motor Fuels and Petroleum Products, March 12, 2011.

^A Instead of the standards in columns B and C, a registered supplier may elect to comply with the standards contained in column A, and R20-2-751 (F), (G), and (H) for the use of the PM.

^B Maximum oxygen content shall comply with the EPA oxygenate waiver requirements. A registered supplier shall certify all Arizona CBG using fuel ethanol as the oxygenate beginning November 1 through March 31. Alternative fuel ethanol contents not less than 2.7% total oxygen may be used if approved by the Director under A.R.S. § 41-2124(D).

Note: Dates represent compliance dates for the owner of a motor fuel dispensing site or fleet vehicle fuel facility.



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