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Standard Specification for Gasoline-like Test Fuel for Compression-Ignition Engines[1]

This standard is issued under the fixed designation D8275; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers the requirements of test fuels suitable for use in certain gasoline compression-ignition engines and vehicles, which have been specifically designed to operate on the fuel described in this specification. These gasoline-like fuels, which may contain certain gasoline blending components, are henceforth referred to in this specification as "gasoline compression-ignition (GCI) test fuels."

1.1.1 The GCI test fuels described by this specification are only intended for use by engine and vehicle manufacturers in the continuing development of appropriately designed compression-ignition engines that can take advantage of certain chemical and physical properties of GCI test fuels to achieve higher efficiency and lower emissions (henceforth referred to as "GCI engines"). These GCI test fuels are not intended for use by the general public.

1.1.2 GCI engines include only those engines that directly inject fuel into the combustion chamber, and rely on autoignition of the fuel to initiate combustion part or all the time. Although various combustion strategies may be used depending on the fuel and engine operating condition, the level of fuel stratification is typically decreased in GCI engines under certain operating conditions relative to traditional diesel compression-ignition engines. Engines that use an auxiliary ignition source (such as a spark plug) some but not all of the time could qualify as GCI engines.

1.1.3 The GCI test fuels covered in this specification may contain oxygenates, such as alcohols and ethers. Recommended limits on the type and concentration of specific oxygenates are provided in Appendix X3.

1.2 This specification provides a description of GCI test fuels for automotive engines that are not currently widely available to the general public, but are being developed and require defined standard test fuels. Commercial fuels meeting the same or similar requirements as the GCI test fuels described in this specification could become available to the general public if/when such engines are introduced into commerce; however use of this specification by the general public would require significant modifications. The specification is under continuous review, which can result in revisions based on changes in fuel, automotive requirements, test methods, or a combination thereof. All users of this specification, therefore, should refer to the latest edition.

1.3 Traditional diesel compression-ignition engines and fuel systems are designed for use with fuel, which has a lower volatility, higher flash-point, and higher viscosity than GCI test fuels. Such engines are therefore usually unsuitable for use with GCI test fuels. Certain hardware modifications may be required for the safe use of low flash-point, GCI test fuels.

NOTE 1—If there is any doubt as to the latest edition of Specification D8275, contact ASTM International Headquarters.

1.4 The values stated in SI units are to be regarded as the standard. Any other values given are provided for information only.

[1] This specification is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.A0.01 on Gasoline and Gasoline-Oxygenate Blends.

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

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter
D381 Test Method for Gum Content in Fuels by Jet Evaporation
D525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)
D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)
D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D2699 Test Method for Research Octane Number of Spark-Ignition Engine Fuel
D2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel
D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry
D3237 Test Method for Lead in Gasoline by Atomic Absorption Spectroscopy
D3341 Test Method for Lead in Gasoline—Iodine Monochloride Method
D3606 Test Method for Determination of Benzene and Toluene in Spark Ignition Fuels by Gas Chromatography
D3831 Test Method for Manganese in Gasoline By Atomic Absorption Spectroscopy
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4176 Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)
D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products
D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
D4814 Specification for Automotive Spark-Ignition Engine Fuel
D4815 Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C_1 to C_4 Alcohols in Gasoline by Gas Chromatography
D4953 Test Method for Vapor Pressure of Gasoline and Gasoline-Oxygenate Blends (Dry Method)
D5059 Test Methods for Lead and Manganese in Gasoline by X-Ray Spectroscopy
D5191 Test Method for Vapor Pressure of Petroleum Products and Liquid Fuels (Mini Method)
D5291 Test Methods for Instrumental Determination of Carbon, Hydrogen, and Nitrogen in Petroleum Products and Lubricants
D5443 Test Method for Paraffin, Naphthene, and Aromatic Hydrocarbon Type Analysis in Petroleum Distillates Through 200 °C by Multi-Dimensional Gas Chromatography
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 and Liquid Fuels (Mini Method—Atmospheric)
D5580 Test Method for Determination of Benzene, Toluene, Ethylbenzene, *p/m*-Xylene, *o*-Xylene, C_9 and Heavier Aromatics, and Total Aromatics in Finished Gasoline by Gas Chromatography
D5769 Test Method for Determination of Benzene, Toluene, and Total Aromatics in Finished Gasolines by Gas Chromatography/Mass Spectrometry
D5842 Practice for Sampling and Handling of Fuels for Volatility Measurement
D5854 Practice for Mixing and Handling of Liquid Samples of Petroleum and Petroleum Products
D6079 Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR)
D6378 Test Method for Determination of Vapor Pressure (VP_X) of Petroleum Products, Hydrocarbons, and Hydrocarbon-Oxygenate Mixtures (Triple Expansion Method)
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
D7220 Test Method for Sulfur in Automotive, Heating, and Jet Fuels by Monochromatic Energy Dispersive X-ray Fluorescence Spectrometry

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

D7667 Test Method for Determination of Corrosiveness to Silver by Automotive Spark-Ignition Engine Fuel—Thin Silver Strip Method
D7671 Test Method for Corrosiveness to Silver by Automotive Spark–Ignition Engine Fuel–Silver Strip Method
D7757 Test Method for Silicon in Gasoline and Related Products by Monochromatic Wavelength Dispersive X-ray Fluorescence Spectrometry
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

3. Terminology

3.1 *Definitions:*

3.1.1 For general terminology, refer to Terminology D4175.

3.1.2 *dry vapor pressure equivalent, DVPE, n*—value calculated by a defined correlation equation that is expected to be comparable to the vapor pressure value obtained by Test Method D4953, Procedure A.

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

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

3.1.5 *octane sensitivity, n*—the mathematical difference between research octane number (RON) and motor octane number (MON) ~~(S~~ (octane sensitivity = RON – MON).

3.1.5.1 *Discussion*—
The terms octane sensitivity and octane number sensitivity are used synonymously.

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *gasoline compression-ignition test fuel, n*—a homogeneous, volatile mixture of liquid hydrocarbons with or without oxygenates, generally containing small amounts of additives, suitable for use as a fuel in certain gasoline compression-ignition engines and vehicles.

3.2.2 *gasoline compression-ignition engine, n*—a type of internal combustion engine in which gasoline or gasoline-like fuel is directly injected into the combustion chamber, and which uses a compression-ignition process to initiate combustion under some operating conditions.

4. Performance Requirements

4.1 The fuel shall conform to the requirements of Table 1. The significance of each of the properties of this specification is shown in Appendix X2.

4.1.1 The reader is advised to review other applicable national, state, provincial, or local requirements.

4.1.2 The following applies to all specified limits in this specification: For purposes of determining conformance with this specification, 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 the rounding method of Practice E29. All digits associated with property limits in this specification are significant unless otherwise noted.

4.2 Seasonal and regional volatility classes are not specified as the limits in this specification are provided for research and development purposes only, and are not meant for use by the general public.

4.3 Additional recommended property limits for GCI test fuel formulation are provided in Table X3.1. These property requirements are provided as guidance for continued research and development purposes. Those properties which are subsequently shown to be required for GCI vehicle performance will be included in Table 1 in future versions of this specification.

TABLE 1 GCI Test Fuel Specifications

Property	Limit	ASTM Test Method
Lead content, g/L, max	0.013	D3237 or D5059
Sulfur, mg/kg, max	10.	D1266, D2622, D3120, D5453, D7039 or D7220
Manganese content, mg/L, max	0.25	D3831
Copper strip corrosion, max (3 h at a minimum control temperature of 50 °C)	No. 1	D130
Silver strip corrosion, max (2 h at a minimum control temperature of 50 °C)	No. 1	D7667 or D7671
Solvent-washed gum content, mg/100 mL, max	5	D381
Oxidation stability, minutes, min	240.	D525
Vapor pressure, at 37.8 °C, kPa		D4953, D5191, D5482, or D6378
min	44	
max	103	
Distillation Temperature, °C, at percent evaporated		D86
Initial boiling point,		
min	30.	
max	160.	
End point, max	360.	
Distillation residue, % by volume, max	2	D86

5. Workmanship

5.1 The GCI test fuel shall be visually free of undissolved water, sediment, and suspended matter; it shall be clear and bright at the fuel temperature at the point-of-custody transfer or at a lower temperature agreed upon by the purchaser and seller.

5.1.1 Test Method D4176 can be helpful for evaluating the product.

5.1.2 *Avoiding Water Haze and Phase Separation*—GCI test fuel should not contain a separate water or water-alcohol phase at the time it is introduced into a vehicle or equipment fuel tank or under the conditions the fuel is used. Water that is dissolved in fuel at the point of use does not generally cause engine problems. However, if excess water is present in gasoline compression-ignition fuel, a separate phase, either "free water" or a water-alcohol mixture, can form. Either condition can lead to engine damage, or the engine failing to start or operate properly. A separated water-rich phase can be observed as a haze, water droplets or a distinct lower layer. This lower aqueous phase can be corrosive to many metals and the engine cannot operate on it. Similarly, the upper hydrocarbon phase may no longer meet volatility properties. See Appendix X8 in Specification D4814 for additional information on water haze and phase separation.

5.1.2.1 GCI test fuel should be resistant to phase separation or undissolved matter at the lowest temperatures to which it is likely to be subjected, dependent on the time and place of its intended use.

NOTE 2—Solubility is temperature dependent. As this fuel cools, water or water-alcohol and some high molecular weight additives can become insoluble.

5.2 The GCI test fuel shall also be free of any adulterant or contaminant that can render the fuel unacceptable for its commonly used applications.

5.2.1 Manufacturers and blenders of GCI test fuel shall avoid blending stocks (for example, purchased used toluene solvents or improperly recycled ethanol) contaminated by silicon-containing materials. Silicon contamination can lead to fouled vehicle components requiring parts replacement and repairs. Test Method D7757 is a procedure for determining silicon content but no specification limits have been established for silicon.

6. Sampling, Containers, and Sample Handling

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

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

6.3 The correct sample volume and appropriate container selection are important decisions that can impact test results. Refer to

Practice D4306 for aviation fuel container selection for tests sensitive to trace contamination. Refer to Practice D5854 for procedures on container selection and sample mixing and handling.

6.4 For volatility determination of a sample, refer to Practice D5842 for special precautions recommended for representative sampling and handling techniques.

7. Test Methods

7.1 The requirements of this specification shall be determined in accordance with following the methods. The scopes of some of the following test methods do not include gasoline-ethanol blends or other gasoline-oxygenate blends. Refer to the listed test methods to determine applicability or required modifications for use with gasoline-oxygenate blends. The precision of these test methods can differ from the reported precisions when testing ethanol- or oxygenate-containing blends.

7.1.1 *Distillation*—Test Method D86.

7.1.2 *Vapor Pressure*—Test Methods D4953, D5191, D5482, or D6378.

7.1.2.1 When using Test Method D6378, determine VP_4 at 37.8 °C (100 °F) using a sample from a 1 L container and convert to DVPE (Test Method D5191 equivalence) using:

$$\text{Predicted DVPE} = VP_{4\ 37.8\ °C} - 1.005\ \text{kPa} \quad (1)$$

$$\text{Predicted DVPE} = VP_{4\ 37.8\ °C} - 0.15\ \text{psi} \quad (2)$$

7.1.3 *Corrosion, for Copper*—Test Method D130, 3 h at 50 °C (122 °F).

7.1.4 *Solvent-Washed Gum Content*—Test Method D381, air jet apparatus.

7.1.5 *Sulfur*—Test Methods D1266, D2622, D3120, D5453, D7039, or D7220.

7.1.6 *Lead*—Test Methods D3341 or D5059 (Test Methods A or B). For lead levels below 0.03 g/L (0.1 g/U.S. gal), use Test Methods D3237 or D5059 (Test Method C).

7.1.7 *Oxidation Stability*—Test Method D525.

7.2 Tests applicable to gasoline are not necessarily applicable to its blends with oxygenates. Consequently, the type of fuel under consideration shall first be identified to select applicable tests. Test Method D4815 provides a procedure for determining oxygenate concentration in mass percent. Test Method D4815 also includes procedures for calculating mass oxygen content and oxygenate concentration in volume percent. Appendix X4 in Specification D4814 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.

8. Keywords

8.1 alcohol; automotive fuel; copper strip corrosion; corrosion; distillation; driveability; ethanol; ether; fuel; gasoline; gasoline-alcohol blend; gasoline compression-ignition; gasoline compression-ignition engine fuel; gasoline-ethanol blend; gasoline-ether blend; gasoline-oxygenate blend; induction period; lead; methanol; MTBE; oxidation stability; oxygenate; oxygenate detection; phosphorous; solvent-washed gum; spark-assisted gasoline compression-ignition; sulfur; unleaded fuel; vapor pressure; volatility

APPENDIXES

(Nonmandatory Information)

X1. BACKGROUND ON GASOLINE COMPRESSION-IGNITION COMBUSTION AND FUELS

X1.1 Various advanced compression-ignition engines have been proposed as technologies that combine aspects of gasoline and diesel engine technology. Gasoline engines generally have the advantage of simple engine and aftertreatment system designs, whereas diesel engines can typically achieve higher efficiency—albeit at greater cost and complexity. Various advanced compression-ignition strategies have been investigated in the research community for use with gasoline or gasoline-like fuels, including homogeneous charge compression-ignition (HCCI) (**1**)[3], reactivity-controlled compression-ignition (RCCI) (**2-6**), and partially-premixed compression-ignition (PPCI) (**7-19**). Although certain aspects of the engine hardware and control strategy may differ between these concepts, they share a common objective with GCI engines of low emissions, high efficiency combustion of gasoline or gasoline-like fuels in a compression-ignition engine.

X1.2 Increased efficiency of GCI engines relative to traditional spark-ignition (SI) engines is driven by several factors. Compression-ignition engines do not experience traditional engine knock observed in SI engines, and globally lean operation significantly reduces pumping losses while improving thermodynamic efficiency. At the same time, greater mixing of fuel and air prior to combustion reduces soot production relative to conventional mixing-controlled (diesel) combustion and may also reduce pressure requirements for the fuel injection system. High rates of exhaust gas recirculation (EGR) are typically used to limit peak temperatures and oxygen concentrations, thereby reducing engine-out emissions of nitrogen oxides (NOx). While various combustion strategies may be employed, key featuresof GCI combustion include faster fuel-air mixing, an increased portion of premixed combustion, improved air utilization, and in some cases, a greater degree of separation between the end of injection and start of combustion. These features are partially enabled by the use of gasoline-like fuels which have a higher vapor pressure, lower boiling range, and longer ignition delay than diesel fuels.

X1.3 Because GCI engines utilize a combustion process which is different from traditional mixing-controlled, diesel compression-ignition engines, the optimal fuel for these engines is also different. Many previous works have explored the effect of fuel properties such as fuel reactivity, distillation, and chemical composition on combustion behavior, engine performance, and emissions under partially-premixed combustion conditions. Fuels tested in these studies include gasoline (**2**, **8**, **9**, **14-18**, **20-35**), diesel (**9**, **15**, **16**, **18**, **20-22**, **24-28**, **30-32**, **36-41**), gasoline-diesel blends (**25**, **30-32**, **37**, **38**, **41**, **42**), low-octane gasolines (**8**, **9**, **14**, **17**, **21-23**, **25**, **27-29**, **35**, **39-46**), model fuel blends (**9**, **14**, **23**, **25**, **37**, **39**, **41**), and other blends of petroleum-based fuels with solvents, oxygenated compounds and additives (**16**, **22**, **25**, **26**, **37**, **39**, **40**, **44**). A large number of studies have shown that fuel reactivity (as measured by RON, MON, cetane number, or homogeneous ignition delay) plays an important role in GCI engine performance (**7-9**, **14-16**, **18**, **20-23**, **25**, **30**, **32**, **35**, **36**, **39**, **44**, **47**), however the potential exists for other fuel effects pertaining to physical properties or chemical composition to also affect combustion, performance, or emissions in GCI engines. Accordingly, recommended property limits for achieving consistent test results between various GCI engine research and development laboratories have been provided in Appendix X3.

X2. SIGNIFICANCE OF ASTM SPECIFICATION FOR GASOLINE COMPRESSION-IGNITION TEST FUEL

X2.1 General

X2.1.1 Distillation and vapor pressure define the general characteristics of GCI test fuel. Other characteristics relate to: 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. No octane number or anti-knock requirements are specified as GCI engines do not experience conventional spark-ignition engine knock.

[3] The boldface numbers in parentheses refer to the list references at the end of this standard.

X2.1.2 Gasoline compression-ignition test fuel 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 the fuel shall 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. Some of the limits specified in this specification are established on the basis of the broad experience and close cooperation of producers of fuel, manufacturers of automotive equipment, and users of both.

X2.2 Volatility

X2.2.1 In GCI engines, the fuel is metered in liquid form through the fuel injector, which injects the fuel into the combustion chamber during the intake or compression stroke. Fuel volatility will determine the phase behavior of the fuel in the fuel tank, pumps, lines, and injectors, as well as the degree of mixing that occurs in the combustion chamber before combustion.

X2.2.2 Fuels in the gasoline boiling range are expected to mix more readily with air than middle-distillate or diesel fuels due to their lower viscosity and density, and higher vapor pressure (Table 1). This can reduce local richness during combustion and thus reduce soot formation. At high operating temperatures, fuels can boil in fuel pumps, or lines. If too much vapor is formed, the fuel flow to the engine can be decreased, resulting in loss of power, rough engine operation, or engine stoppage. These conditions are known as "vapor lock." Conversely, fuels with low volatility may vaporize less easily leading to decreased air-fuel mixing in the combustion chamber and corresponding changes in engine performance and emissions.

X2.2.3 These conditions can be minimized by proper selection of volatility requirements, but cannot always be avoided. For example, during spring and fall, a fuel of volatility suitable for satisfactory starting at low ambient temperatures can cause problems in some engines under higher ambient temperature operating conditions.

X2.2.4 Seasonal and regional vapor pressure/distillation classes are not provided as the fuel is only intended for testing and development purposes and not widespread distribution.

X2.3 Vapor Pressure

X2.3.1 The vapor pressure of GCI test fuel should be high enough such that the partial pressure of fuel in the gas space in the fuel tank exceeds the upper flammability limit of the fuel under ambient conditions. Fuels with very low volatility may result in formation of a flammable gas mixture in the fuel tank or filling line. As such, a minimum vapor pressure is specified to ensure that flammable gas mixtures in the fuel tank and lines are avoided.

X2.3.2 Test Methods D4953, D5191, D5482, or D6378 provide procedures for determining the vapor pressures of gasoline or gasoline-oxygenate blends.

X2.4 Distillation

X2.4.1 Test Method D86 for distillation provides another measure of the volatility of fuels. Table 1 designates the limits for the initial boiling point and end-point temperature. These distillation characteristics may affect engine, fuel system and vehicle