Designation: D7901 – 20

Standard Specification for Dimethyl Ether for Fuel Purposes[1]

This standard is issued under the fixed designation D7901; 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 dimethyl ether (DME) for use as a fuel in engines specifically designed or modified for DME and for blending with liquefied petroleum gas (LPG). This specification is for use by manufacturers of dimethyl ether, by engine developers of purpose-built engines, in contracts for the purchase of DME for fuel purposes, and for the guidance of consumers of this type of fuel.

NOTE 1—The generation and dissipation of static electricity can create problems in the handling of DME. For more information on the subject, see Guide D4865.

1.2 The values stated in SI units are to be regarded as standard. Units in parentheses are for information only.

1.3 *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.*

1.4 *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]

D1265 Practice for Sampling Liquefied Petroleum (LP) Gases, Manual Method

D1267 Test Method for Gauge Vapor Pressure of Liquefied Petroleum (LP) Gases (LP-Gas Method)

D1838 Test Method for Copper Strip Corrosion by Liquefied Petroleum (LP) Gases

D2158 Test Method for Residues in Liquefied Petroleum (LP) Gases

D2163 Test Method for Determination of Hydrocarbons in Liquefied Petroleum (LP) Gases and Propane/Propene Mixtures by Gas Chromatography

D3700 Practice for Obtaining LPG Samples Using a Floating Piston Cylinder

D4865 Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems

D6667 Test Method for Determination of Total Volatile Sulfur in Gaseous Hydrocarbons and Liquefied Petroleum Gases by Ultraviolet Fluorescence

D6897 Test Method for Vapor Pressure of Liquefied Petroleum Gases (LPG) (Expansion Method)

D7756 Test Method for Residues in Liquefied Petroleum (LP) Gases by Gas Chromatography with Liquid, On-Column Injection

D7828 Test Method for Determination of Residue Composition in Liquefied Petroleum Gas (LPG) Using Automated Thermal Desorption/Gas Chromatography (ATD/GC)

2.2 *Other Documents:*

NFPA 77 Recommended Practice on Static Electricity[3]

ISO/DIS 17196 Dimethyl ether (DME) for fuels—Determination of impurities—Gas chromatographic method[4]

ISO 17197 Dimethyl ether (DME) for fuels—Determination of water content—Karl Fischer titration method[4]

3. Terminology

3.1 *Abbreviations:*

3.1.1 *DME*—dimethyl ether, the chemical compound (CH_3OCH_3).

3.1.2 *LPG*—liquefied petroleum gas.

4. Hazards

4.1 *Warning*—Dimethyl ether is a highly flammable, colorless gas with a faint ether-like odor. It is shipped and stored in a pressurized, liquefied state, much like LPG. Unlike LPG,

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[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.

[3] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

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

dimethyl ether has a wide flammability range and a low autoignition temperature. Further, dimethyl ether in this specification is intended for use in a diesel (compression-ignition) engine. Many users of diesel engines are familiar with the relative safety of storing and handling diesel fuel. However, dimethyl ether has significantly higher flammability hazards than diesel fuel. A leak of dimethyl ether could result in a dangerous fire or explosive situation, but the intrinsic ether-like odor is mild and not alarming, as is the case with odorized natural gas or LP gases. Users of dimethyl ether are advised to determine proper odorization or alternative leak detection precautions.

4.2 Consult a Material Safety Data Sheet for dimethyl ether for additional hazards.

5. Chemical Composition and Other Requirements

5.1 The DME fuel for purpose-built engines and for blending with liquefied petroleum gas shall conform to the requirements prescribed in Table 1.

NOTE 2—Additional information on the physical and chemical properties of dimethyl ether, which are not considered necessary for fuel specification at this point, are in Appendix X1 and are given for information of fuel suppliers, OEMs, and users.

5.2 The properties selected for limitation are chosen from other specifications for DME which have relevance to engine operation and to related experience (for example, LPG).

5.3 The maximum vapor pressure limit shown in Table 1 is given to limit any high vapor pressure components such as gases [CO and CO_2] and also to ensure that the same containers (tanks, tank cars, and rail cars) designed for LPG can be used for DME.

TABLE 1 Detailed Requirements for Dimethyl Ether for Fuel Purposes

Property	Test Method	Requirement
Dimethyl Ether, mass %, min.[A]	D2163	98.5
Methanol, mass %, max.	D2163	0.05
Water, mass %, max.	ISO 17197	0.03
Methyl Formate, mass %	D2163	report
Sulfur, mg / kg, max.[B]	D6667	3
Vapor Pressure, kPa (psig), at 37.8 °C (100 °F), max.	D1267, D6897	758 (110)
Corrosion, Copper Strip, at 37.8 °C (100 °F), max.	D1838	No. 1
Residue	D2158	
Residue on evaporation of 100 mL, mL, max,		0.05
Oil stain observation		pass
Lubricity	—	[C]

[A] The required minimum ensures that DME for fuel purposes will have a minimum estimated cetane number of 55.

[B] The sulfur limit does not include the sulfur from an odorant such as ethyl mercaptan that might be required by some regulatory agencies in some fuel applications. Note that addition of 1 pound of ethyl mercaptan per 10 000 US gallons will increase the sulfur content of DME by 14 milligrams sulfur per litre of DME or 21 milligrams sulfur per kilogram of DME.

[C] Experience in both laboratory and full scale vehicle testing indicates pure DME has poor natural lubricity. Adequate precautions shall be taken to ensure the lubricity is sufficient to meet the needs of the end use application. At present, no industry accepted test method or limit value is available to define the lubricity of highly volatile liquid fuels such as DME. Until such a test is available, suppliers of DME intended for use as a fuel in compression-ignition engines shall consult the engine or vehicle manufacturer for guidance on appropriate lubricity requirements.

NOTE 3—It is expected that additional requirements for specifying dimethyl ether for fuel applications could be required as purpose-built engines and other applications develop for DME and DME – LPG blends, and such additional requirements would be balloted for inclusion into this specification, based on need and technical data.

6. Workmanship, Finish, and Appearance

6.1 DME for fuel use in engines designed for DME and for blending with liquefied petroleum gas shall have a colorless appearance and not contain any components or contaminants that would be detrimental to the intended use of the material.

7. Sampling

7.1 Review all intended test methods prior to sampling to understand the importance and effects of sampling technique, proper containers, and special handling required for each test method.

7.2 Samples shall be representative of the batch of product and shall be collected from an appropriate storage container (typically an aboveground storage tank) or pipeline by a suitable sampling procedure such as Practice D1265 or Practice D3700.

7.3 *Sample Size*—A minimum of 1 litre is recommended.

7.3.1 Follow the same safety procedures when sampling DME as when sampling LPG, and leave an ullage space of at least 20 % in a high pressure sampling cylinder.

8. Test Methods

8.1 The requirements of this specification shall be determined in accordance with the methods listed below. The scopes of some of the test methods listed below do not include dimethyl ether. Refer to the listed test methods to determine applicability or required modifications for use with dimethyl ether. The precision of these test methods can differ from the reported precisions when testing dimethyl ether.

8.2 *Composition*—Test Method D2163.

8.2.1 Laboratory experience has shown that Test Method D2163 requires the use of a 150 metre methyl silicone column in order to analyze samples of DME.

8.3 *Water*—ISO 17197. While ISO 17197 is written for both coulometric and volumetric Karl Fischer reagents, only coulometric Karl Fischer reagents shall be used for DME testing due to the low water concentration levels present in DME.

8.4 *Sulfur*—Test Method D6667 should be used for sulfur determination.

8.5 *Vapor Pressure*—Test Methods D1267 and D6897 may be used for vapor pressure determination. In case of dispute, Test Method D1267 shall be the referee test method.

8.6 *Corrosion*—Test Method D1838.

8.7 *Residue*—Test Method D2158.

9. Keywords

9.1 dimethyl ether; DME

APPENDIXES

(Nonmandatory Information)

X1. PHYSICAL AND CHEMICAL PROPERTIES OF DIMETHYL ETHER

X1.1 A selection of physical and chemical properties of dimethyl ether, as outlined in Table X1.1, has been assembled from a variety of sources. These are believed to be the best available data. The table will be updated as new or more reliable data is developed.

X1.2 Additional information on the properties of dimethyl ether can be found in the "DME Handbook Supplement" [English Edition] [ISBN 978-4-9903839-1-6], published October, 2011.[5]

[5] Available from Japan DME Forum (JDF), 3F Shinsei Bldg. 6-5-5, Shinbashi, Minato-ku, Tokyo 105-0004. Tel: +81-3-5403-0035, Fax: +81-3-5403-0038, Email: info@dmeforum.jp, Website: www.dmeforum.jp/

TABLE X1.1 Physical and Chemical Properties of Dimethyl Ether

Property	Value
Chemical Formula	CH_3OCH_3
CAS No.	115-10-6
Molecular weight, g/mol	46.07
Melting point, °C	-141.5
Boiling point, °C	-25.1
Vapor pressure at 20 °C, kPa	510
Critical temperature, °C	126.85
Critical pressure, MPa	5.37
Critical volume, cm^3/mol	178
Liquid density at 20 °C, g/cm^3	0.67
Specific Gravity of DME Vapor (versus Air)	1.59
Color	Colorless
Odor	Faint "ether" smell
Flammability Limits in Air, vol %	3.4 to 17
Estimated Cetane Number	55
Calorific Value, LHV, kcal/L, 20 °C (net heat of combustion)	4600
DME solubility in water, g/100 mL at 18 °C	7
Solubility parameter, $(cal/cm^3)^{0.5}$	7.3
Wobbe Index, kJ/m^3	46198
Acentric factor	0.204

X2. SIGNIFICANCE OF ASTM SPECIFICATIONS FOR DIMETHYL ETHER FOR FUEL APPLICATIONS

X2.1 DME is a new fuel that could address environmental and fuel security issues. A fuel specification for DME is necessary for several reasons:

(1) To give manufacturers of DME, intended to be used as a fuel, a specification to meet;

(2) To give OEMs a standard specification they can use to design new, purpose-built engines and applications. Some heavy-duty vehicle manufacturers are actively developing engines specifically for DME and have announced their support for the development of a standard fuel specification.

(3) Since DME can be produced from biomethane, a specification encourages development of this as an initial biofuel for commercial and consumer uses in purpose-built engines.

(4) To establish a product specification for DME for use in a blend with LPG. DME is already being used in countries such as China in a blend with LPG, and this practice could expand.

(5) The California Department of Food and Agriculture, Division of Measurement Standards (CDFA) is a strong proponent of the development of a DME fuel standard. CDFA has jurisdiction within the State over fuel quality standards as they relate to vehicle performance and driveability. California law requires that all fuel sold or distributed within the State have a fuel specification established by a consensus organization, such as ASTM or SAE. This definition does not preclude the use of an ISO standard or ISO test methods.

X2.1.1 This initial specification is based on the best, but limited, available information about DME in fuel applications. This specification will allow development of purpose-built applications (such as diesel engines) using a consistent fuel, and it is expected that modifications could be proposed to this specification as new applications and equipment are developed.

X2.2 Composition

X2.2.1 *Dimethyl Ether*—Commercial production processes for converting natural gas or biomethane into dimethyl ether produce a high purity product. Therefore, setting the minimum composition of DME at 98.5 % by mass is a reasonable compromise between the higher cost of very high purity DME used for specialty chemical applications, such as aerosol propellants, and the lower manufacturing cost of DME (for example, no costly purification steps) that give a product suitable for fuel applications. Setting a high minimum concentration for DME ensures that DME for fuel purposes will have both a minimum concentration of contaminants and a minimum estimated 55 cetane number without the need to specify this requirement in Table 1.

X2.2.2 *Methanol*—The concentration of methanol is limited due to concerns about potential corrosivity and material incompatibility.

X2.2.3 *Water*—The concentration of water is limited to minimize potential freezing problems in DME – LPG mixtures and concerns with hydrate formation.

X2.2.4 *Methyl Formate*—While methyl formate should not be present in DME based on its physical properties (much higher boiling point than DME), concerns have been expressed about potential corrosion and instability issues, so a report requirement is proposed.

X2.3 *Sulfur*—DME production processes require very low sulfur content to prevent poisoning production catalysts, so the sulfur limit is set very low to recognize the negligible sulfur in DME as produced, which is much lower than the sulfur limit in LPG.

X2.3.1 The sulfur limit does not include the sulfur from an odorant, such as ethyl mercaptan, that might be required by some regulatory agencies in some fuel applications. Note that addition of 1 pound of ethyl mercaptan per 10 000 US gallons will increase the sulfur content of DME by 14 milligrams sulfur per litre of DME or 21 milligrams sulfur per kilogram of DME.

X2.4 *Vapor Pressure*—The vapor pressure limit is set at the sum of the vapor pressures of DME and contaminants such as methanol, CO, CO_2, and 1 % propane (consistent with the draft ISO DME fuel specification) to limit gases and volatile contaminants. Since this pressure is much lower than the vapor pressure of propane, the same storage and transportation tanks and containers used for LPG can be used for DME.

X2.5 *Copper Corrosion*—While aggressive sulfur species are unlikely to be present in DME as produced, there is a risk of pick-up of sulfur species during distribution in LPG facilities, so this requirement, set at the same limit as for Special Duty Propane, is in the specification to protect customers' equipment against potential corrosion.

X2.6 *Residue*—The limit on residue is set at the same limit as required in Special Duty / HD-5 propane. While contamination of DME by residues is not anticipated in current production processes, there is a risk of pick-up of heavier contaminants during distribution in LPG facilities, so this requirement is in the specification to protect customers' equipment. Test Methods D7756 and D7828 are gas chromatographic procedures for measurement of heavier soluble residues that could be present in LPG, and these procedures could be useful for evaluating residues in DME.

X2.7 Table X2.1 shows limits for properties that have been suggested by engine manufacturers as requiring limitation; however, no technical justification has been provided for