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Standard Specification for Natural Gas, Hydrogen Blends for Use as a Motor Vehicle Fuel[1]

This standard is issued under the fixed designation D8487; 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 defines the minimum fuel quality requirements for gaseous fuels consisting primarily of methane blended with volume fraction of up to 10 % hydrogen (H_2) when used as an internal combustion engine fuel.

1.2 This specification defines the criteria for blending hydrogen with natural gas, biogas, or renewable natural gas (RNG) and then compressed into compressed natural gas (CNG) for use as a fuel for internal combustion engines in motor vehicles.

1.3 The total volume fraction of hydrogen within the fuel shall consist of hydrogen contained in the natural gas, biogas, or renewable gas and any additional hydrogen blended into the fuel mixture.

1.4 This specification covers the needs of internal combustion engines designed for use in motor vehicles.

1.5 This specification applies to the fuel as delivered into the on-board fuel tanks of a motor vehicle as a compressed gas.

1.6 This specification is not a natural gas pipeline standard; those requirements are determined by national and regional tariffs.

1.7 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.8 *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.*

1.9 *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]

D1142 Test Method for Water Vapor Content of Gaseous Fuels by Measurement of Dew-Point Temperature
D1945 Test Method for Analysis of Natural Gas by Gas Chromatography
D3588 Practice for Calculating Heat Value, Compressibility Factor, and Relative Density of Gaseous Fuels
D4150 Terminology Relating to Gaseous Fuels
D4468 Test Method for Total Sulfur in Gaseous Fuels by Hydrogenolysis and Rateometric Colorimetry
D5454 Test Method for Water Vapor Content of Gaseous Fuels Using Electronic Moisture Analyzers
D5504 Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Chemiluminescence
D6228 Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Flame Photometric Detection
D6968 Test Method for Simultaneous Measurement of Sulfur Compounds and Minor Hydrocarbons in Natural Gas and Gaseous Fuels by Gas Chromatography and Atomic Emission Detection
D7165 Practice for Gas Chromatograph Based On-line/At-line Analysis for Sulfur Content of Gaseous Fuels
D7493 Test Method for Online Measurement of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatograph and Electrochemical Detection
D7551 Test Method for Determination of Total Volatile Sulfur in Gaseous Hydrocarbons and Liquefied Petroleum Gases and Natural Gas by Ultraviolet Fluorescence
D7606 Practice for Sampling of High Pressure Hydrogen and Related Fuel Cell Feed Gases
D7607 Test Method for Analysis of Oxygen in Gaseous Fuels (Electrochemical Sensor Method)
D7650 Practice for Sampling of Particulate Matter in High Pressure Gaseous Fuels with an In-Stream Filter

[1] This specification is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.92 on Terminology Classification and Specifications.

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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.

D7651 Test Method for Gravimetric Measurement of Particulate Concentration of Hydrogen Fuel
D7833 Test Method for Determination of Hydrocarbons and Non-Hydrocarbon Gases in Gaseous Mixtures by Gas Chromatography
D7904 Test Method for Determination of Water Vapor (Moisture Concentration) in Natural Gas by Tunable Diode Laser Spectroscopy (TDLAS)
D7941 Test Method for Hydrogen Purity Analysis Using a Continuous Wave Cavity Ring-Down Spectroscopy Analyzer
D8221 Practice for Determining the Calculated Methane Number (MN_C) of Gaseous Fuels Used in Internal Combustion Engines
D8230 Test Method for Measurement of Volatile Silicon-Containing Compounds in a Gaseous Fuel Sample Using Gas Chromatography with Spectroscopic Detection
D8455 Test Method for Speciated Siloxane GC-IMS Analyzer Based On-line for Siloxane and Trimethylsilanol Content of Gaseous Fuels
D8251 Practice for Determining Compressor Oil Carryover in Compressed Natural Gas Used as a Natural Gas Motor Vehicle Fuel

2.2 *ISO Standards:*[3]
ISO 6976 Natural gas—Calculation of calorific values, density, relative density and Wobbe index from composition
ISO 10715 Natural gas—Sampling Guidelines

2.3 *ASHRAE Standard:*[4]
American Society of Heating, Refrigerating and Air Conditioning Engineer's (ASHRAE) Handbook 1989 Fundamentals Volume

3. Terminology

3.1 For definitions of general terms used in D03 Gaseous Fuels standards, refer to Terminology D4150.

3.2 *Abbreviations:*

3.2.1 *CNG*—compressed natural gas

3.2.2 *MN*—methane number

3.2.3 *MNc*—calculated methane number

3.2.4 *RNG*—renewable natural gas

4. Sampling

4.1 Review relevant test methods prior to sampling to understand the importance and effects of sampling technique, proper containers, and any special handling required for each test method.

4.2 Samples shall be collected directly from the fuel dispenser.

4.3 Samples shall be representative of the product as dispensed into an on-board motor vehicle fuel tank and shall be collected by a suitable sampling procedure.

NOTE 1—This standard is applicable at the point of delivery into the vehicles on-board fuel tank.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

[4] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

TABLE 1

Substance/Property	Units	Test Methods	MNc 65	MNc 75
Hydrogen	% by volume, max	D1945, D7833	10	10
Calculated Methane Number	MNc per Practice D8221, min	D8221	65	75
Wobbe Index (based on Higher Heating Value)[A]	MJ/m^3	ISO 6976	46 to 53	46 to 53
Lower Heating Value[B]	MJ/m^3, min	D3588	33.2	33.2
Oxygen	% by volume, max	D1945, D7607, D7833	1	1
Water Dew Point max at 24,821 kPa[C]	°C below the 99.0 % winter design temperature at dispenser	D1142, D5454, D7904	6	6
Total Sulfur (Includes odorant)[D]	ppmv, max	D4468, D5504, D6228, D6968, D7165, D7493, D7551	5	5
Hydrogen Sulfide[E]	ppmv, max	D4468, D5504, D6228, D6968, D7165, D7493, D7551, D7833	5	5
Maximum Particulates	mg/kg, max	D7651	1	1
Siloxanes[F]	mg of Si/m^3, max	D8230. D8455	0.1	0.1
Compressor Oil	mg/kg, max	D8251[G]	10	10

[A] Wobbe Index of the gas mixture is calculated based on the Higher Heating Value on a volumetric basis at 101.325 kPa and 15.55 °C reference conditions, divided by the square root of the relative density at the same specified metering reference conditions. ISO 6976 uses the term Superior Heating Value in place of the term Higher Heating Value.
[B] Lower Heating Value is calculated based on at 101.325 kPa and 15.55 °C reference conditions.
[C] Refer to the American Society of Heating, Refrigerating and Air Conditioning Engineer's (ASHRAE) Handbook, 1989 Fundamentals Volume. For the United States, refer to Chapter 24, Table 1, Climatic Conditions for the United States; for Canada, refer to Chapter 24, Table 2, Climatic Conditions for Canada; and for the rest of the world, refer to Chapter 24, Table 3, Climatic Conditions of Other Counties. For regions not listed, it is recommended that this reference be consulted for methodology used to calculate the 99 % minimum temperature.
[D] Report in ppmv [μmol of S from all Sulfur compounds/mol of Gas]. As a minimum, total sulfur compounds include, for example, hydrogen sulfide (H_2S), carbonyl sulfide (COS), carbon disulfide (CS_2) Sulfides, thiols, and mercaptans. (See Appendix X1.)
[E] Report in ppmv [μmol of S from H_2S/mol of Gas]. Refer to Appendix X2.
[F] Reference conditions for Test Method D8230 are 101.325 kPa and 25 °C. G Work Item: Practice for Determining Compressor Oil Carryover in Compressed Natural Gas Used as a Natural Gas Motor Vehicle Fuel.
[G] Work Item: Practice for Determining Compressor Oil Carryover in Compressed Natural Gas Used as a Natural Gas Motor Vehicle Fuel.

4.4 *Sample Size*—A volume of sample suitable for performing fuel quality measurements as listed in Table 1 is required. This should be determined in consultation with the testing laboratory.

4.5 Follow all safety procedures when sampling natural gas.

4.5.1 **Warning—**Natural gas-hydrogen blends are a highly flammable substances and poses an asphyxiation hazard. Always perform measurements in a well-ventilated location in the absence of flames or spark sources. Compress gas containers can pose an explosion hazard if not handled properly. Compressed gases are stored at high pressures and can pose both an explosion and freezing hazard because of a sudden release of gas.

5. Detailed Chemical Composition, and Other Requirements

5.1 Natural gas-hydrogen blends gas used as a fuel for internal combustion engines in motor vehicles fuel shall conform to the detailed requirements of Table 1.

5.2 The criteria contained within this specification were primarily constructed from data collected from North American natural gas distribution systems and engine and vehicle manufacturers. As the data ensemble increases, this specification may be revised based upon the additional data.

6. Workmanship

6.1 The gaseous fuel shall be free of any adulterants or contaminants that can render the fuel unacceptable for its intended use in an internal combustion engine.

7. Test Methods

7.1 Requirements satisfying this specification shall be determined in accordance with the methods listed below. Laboratories shall validate their analytical systems' ability to determine the test parameters when the gas mixture contains hydrogen before conducting any testing. Unless otherwise stated standard conditions of 101.325 kPa and 15.55 °C apply to all test methods.

7.2 *Hydrogen*—Test Methods D1945 or D7833. The composition shall be calculated in % by volume.

7.3 *Composition*—Test Method D1945 or D7833. Composition values shall be calculated in % by volume. The volume composition of components used to determine MNc shall be reported for concentrations greater than or equal to 0.1 % by volume. Refer to Practice D8221 for guidance.

7.4 *Calculated Methane Number MNc*—Practice D8221. The MNc is determined from the composition of the fuel.

7.5 *Wobbe Index*—ISO 6976-95. The Wobbe Index shall be calculated based on the higher heating value at the reference conditions of 101.325 kPa and 15.55 °C.

7.6 *Lower Heating Values*—Test Method D3588. Calculations shall be made at the reference conditions of 101.325 kPa and 15.55 °C.

7.7 *Oxygen*—Test Methods D1945, D7833 or D7607. Test Method D7833 is preferred.

7.8 *Water Dew Point*—Test Methods D1142, D5454, or D7904.

7.9 *Total Sulfur*—Test Methods D4468, D5504, D6228, D6968, D7165, D7493, or D7551. The concentration of sulfur containing all compounds is determined and shall be reported as Total Sulfur in part per million by volume (µmol of S from all sulfur compounds/mol of Gas).

7.10 *Hydrogen Sulfide*—Test Methods D4468, D5504, D6228, D6968, D7165, D7493, or D7551. The concentration of hydrogen sulfide is determined and shall be reported as Hydrogen Sulfide as Sulfur in part per million by volume (µmol of S from H_2S/mol of Gas).

7.11 *Particulate Concentration*—Test Method D7651. Particulate concentration shall be determined as mg/kg of gaseous fuel.

7.12 *Siloxanes*—Test Method D8230. Siloxanes compounds measure and results shall be determined as total silicon.

8. Keywords

8.1 biogas; calculated methane number; CNG; compressed natural gas; hydrogen blends; MNc; natural gas; renewable natural gas; RNG

APPENDIXES

(Nonmandatory Information)

X1. SIGNIFICANCE OF ASTM SPECIFICATIONS FOR BLENDED-HYDROGEN NATURAL GAS FOR MOTOR VEHICLE FUEL APPLICATIONS

X1.1 *Methane Number*—The methane number (MN) is a measure of the resistance of the gaseous fuel to autoignition (knock) when used in an internal combustion engine. The relative merits of gaseous fuels from different sources and having different compositions can be compared readily based on their methane numbers. Methane number is an experimental determination of a gaseous fuel's resistance to knock based on a Cooperative Fuel Research Motor Octane Number (MON) test engine and indicated by the volume of methane in a blend with hydrogen.

X1.2 *Calculated Methane Number (MNc)*—The calculated methane number (MNc) is based on an algorithm that approximates the experimentally determined methane number. This calculation is an optimization of varying sequences of ternary and binary gas component tables generated from the composition of a gaseous fuel sample. This calculation method applies to gaseous fuels comprising of hydrocarbons from methane to hexane and greater (C6+); carbon monoxide; hydrogen; hydrogen sulfide; nitrogen; and carbon dioxide.

X1.3 *Wobbe Index (WI)*—The Wobbe Index is a measure of the energy density of a gaseous fuel mixture.

X1.4 *Lower Heating Value, also called Net Heating Value*—The amount of energy per volume transferred as heat from the complete, ideal combustion of the gas at standard temperature in which all the water formed by the reaction remains in the vapor state.

X1.5 *Hydrogen*—Hydrogen impacts the MNc and Wobbe Index of gaseous fuel mixtures. Hydrogen can lead to component failure with natural gas engine that are not designed for higher levels of hydrogen. Research is being conducted on increasing the hydrogen concentration within the natural gas supply.

X1.6 *Oxygen*—The oxygen concentration limit is a safety requirement to prevent explosion in the fuel storage and supply systems.

X1.7 *Water Dew Point*—Water can lead to freezing of components within the fueling system. The limit is set at 6 °C below the minimum 99 % temperature as defined in Chapter 24 of American Society of Heating, Refrigerating and Air Conditioning Engineer's (ASHRAE) Handbook, 1989 Fundamentals Volume.

X2. SIGNIFICANCE OF SULFUR CONTAMINANTS IN HYDROGEN-BLENDED NATURAL GAS FOR MOTOR VEHICLE FUEL APPLICATION

X2.1 *Total Sulfur*—The limit on sulfur content is included to protect exhaust emission control systems. For safety reasons, natural gas providers are required to odorize the gas before delivery to customers. The test methods used to determine total sulfur measures the total mass of all sulfur atoms from the gaseous sulfur containing compounds, including hydrogen sulfide, within a fixed volume of the gas mixture and the results are converted to ppmv [µmol S / mol gas] at standard reference conditions of 101.325 kPa and 15.55 °C.

X2.2 *Hydrogen Sulfide*—The limit on hydrogen sulfide is included because it is oxidized during combustion leading to the formation of sulfur dioxide (SO_2), which reacts with water to form Sulfurous Acid. This acid is extremely corrosive to internal combustion engine components. The test methods used to determine hydrogen sulfide measure the total mass of sulfur atoms from the hydrogen sulfide within a fixed volume of the gas mixture and the results are converted to ppmv [µmol S / mol gas] at standard reference conditions of 101.325 kPa and 15.55 °C.

X3. ADDITIONAL CONTAMINANTS

X3.1 *Maximum Particulates*—Particulates can damage the fueling system.

X3.2 *Siloxanes*—Siloxanes are silicon-containing compounds found in biogas from landfills and municipal waste streams. Natural gas contaminated with siloxane compounds has led to fouled engine components (for example, spark plugs, exhaust oxygen sensors, and catalytic converters) requiring parts replacement and repairs. Test Method D8230 has been developed to test for siloxane compounds. An additional test method (Test Method D8455) for determining siloxanes compounds by GC-IMS is under development and awaiting final approval.

X3.3 *Compressor Oil*—Compressor lubricating oils introduced into the natural gas during the compression process. A test method is under development; see Practice D8251.