Designation: D6421 – 20

Standard Test Method for Evaluating Automotive Spark-Ignition Engine Fuel for Electronic Port Fuel Injector Fouling by Bench Procedure[1]

This standard is issued under the fixed designation D6421; 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 test method covers a bench test procedure to evaluate the tendency of automotive spark-ignition engine fuel to foul electronic port fuel injectors (PFI). The test method utilizes a bench apparatus equipped with Bosch injectors specified for use in a 1985-1987 Chrysler 2.2 L turbocharged engine. This test method is based on a test procedure developed by the Coordinating Research Council (CRC) for prediction of the tendency of spark-ignition engine fuel to form deposits in the small metering clearances of injectors in a port fuel injection engine (see CRC Report No. 592).[2]

1.2 The test method is applicable to spark-ignition engine fuels, which may contain antioxidants, corrosion inhibitors, metal deactivators, dyes, deposit control additives, demulsifiers, or oxygenates, or a combination thereof.

1.3 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.

1.4 *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.* Specific precautionary statements are given throughout this test method.

NOTE 1—If there is any doubt as to the latest edition of Test Method D6421, contact ASTM International Headquarters. Other properties of significance to spark-ignition engine fuel are described in Specification D4814.

1.5 *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:*[3]

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D4814 Specification for Automotive Spark-Ignition Engine Fuel

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

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

2.2 *ANSI Standard:*[4]

MC 96.1 American National Standard for Temperature Measurement Thermocouples

2.3 *CARB Standard:*[5]

Test Method for Evaluating Port Fuel Injector (PFI) Deposits in Vehicle Engines

2.4 *Clean Air Act Amendment:*[6]

Clean Air Act Amendments of 1990, Public Law 101–549, Title 1 – Provisions for Attainment and Maintenance of National Air Quality Standards

3. Terminology

3.1 For general terminology, refer to Terminology D4175.

[1] This test method 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.

Current edition approved April 1, 2020. Published April 2020. Originally approved in 1999. Last previous edition approved in 2019 as D6421 – 19. DOI: 10.1520/D6421-20.

[2] "A Program to Evaluate a Bench Scale Test Method to Determine the Deposit Forming Tendencies of Port Fuel Injectors," available from Coordinating Research Council, Inc., 5755 North Point Parkway, Suite 265, Alpharetta, GA 30022, http://www.crcao.org.

[3] 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.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from California Air Resources Board, P.O. Box 2815, Sacramento, CA 95815. (Incorporated by reference in California Code of Regulations, Title 13, Section 2257.)

[6] Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, http://www.access.gpo.gov.

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

3.2 *Definitions:*

3.2.1 *base fuel, n—in automotive spark-ignition engine fuels,* a material composed primarily of hydrocarbons that may also contain oxygenates, anti-oxidants, corrosion inhibitors, metal deactivators, and dyes but does not contain deposit control or lead additives. **D5500**

3.2.1.1 *Discussion*—A jurisdiction may set limits on lead content from all sources.

3.2.2 *deposit control additive, n*—material added to the fuel to prevent or remove deposits in one or more of the engine fuel, intake, and combustion systems. **D5500**

3.2.2.1 *Discussion*—For the purposes of this test method, the performance of a deposit control additive is limited to the electronic port fuel injector tip areas.

3.2.3 *driveability, n—in vehicles equipped with internal combustion engines,* the quality of a vehicle's performance characteristics under a range of conditions as perceived by the operator. **D4814**

3.2.3.1 *Discussion*—The operating conditions may include cold starting and warm-up, acceleration, idling, and hot start. The performance characteristics may include engine hesitation, stumble, and stall. **D4814**

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *cycle, n*—a 15 s pulsing period, followed by a 50 min heating period at 160 °C (320 °F), followed by a 10 min cool-down period.

3.3.2 *electronic port fuel injector (PFI), n*—an electromechanical device used to control fuel flow in an internal combustion engine.

3.3.3 *fouling, v*—formation of carbonaceous deposits on the pintle or metering surfaces of an electronic fuel injector, which reduces fuel flow rate.

3.3.4 *pintle, n*—a needle-like metering device extending beyond the electronic fuel injector body that is part of an electronic fuel injector, which controls flow rate and spray pattern.

3.3.5 *test fuel, n*—base fuel, with or without the addition of a deposit control additive, that is used for evaluation as described in this test method.

4. Summary of Test Method

4.1 This test method describes a procedure for evaluating the formation of deposits in PFIs. The test method includes a bench test procedure that has been shown to rapidly form deposits in fuel injectors and a procedure for determining resultant flow loss.

4.2 This test method uses a simulated fuel system consisting of a fuel pump, filter, pressure regulator, fuel rail, and fuel injectors. A heat source is applied to the fuel injectors to simulate the hot-soak portion of the vehicle test (see Test Method D5598).

4.3 Each test begins with screened injectors that are known to foul. The tips of these four clean fuel injectors are placed in an aluminum block. A stainless-steel internal reservoir is filled with 2 L of the test fuel.

4.4 During one 60 min test cycle, the fuel injectors are pulsed for 15 s, followed by a 50 min hot-soak interval in which the injector aluminum block temperature controller is set at a temperature of 160 °C (320 °F) and the fuel pressure is regulated to 263 kPa (38 psig), followed by a 10 min cool-down period. Flow measurements for each of the injectors are taken at the beginning of the test, after 22 cycles, and at the end of the test at 44 cycles.

4.5 The change in the rate of flow for each injector from the start to the end of the test is used to determine the fouling percentage of each injector.

5. Significance and Use

5.1 Driveability problems in PFI automobiles were first reported in 1984. Deposits are prone to form on the metering surfaces of pintle-type electronic fuel injectors. These deposits reduce fuel flow through the metering orifices. Reductions in metered fuel flow result in an upset in the air-fuel ratio, which can affect emissions and driveability. When heavy enough, these deposits can lead to driveability symptoms, such as hesitation, hard starting, or loss of power, or a combination thereof, that are easily noticed by the average driver and that lead to customer complaints. The mechanism of the formation of deposits is not completely understood. It is believed to be influenced by many factors, including driving cycle, engine and injector design, and composition of the fuel. The procedure in this test method has been found to build deposits in PFIs on a consistent basis. This procedure can be used to evaluate differences in base fuels and fuel additives. A study of PFI fouling was conducted in both the bench test and the vehicle test procedures to obtain a correlation. The vehicle tests were conducted as described in Test Method D5598. The tests were conducted on several base gasolines, with and without additives blended into these base fuels. The PFI bench test proved to be reliable, repeatable, and a good predictor of PFI fouling in test vehicles.

5.1.1 *State and Federal Legislative and Regulatory Action*—Legislative and regulatory activity, primarily by the state of California (see 2.3) and the federal government (see 2.4), necessitate the acceptance of a standard test method to evaluate the PFI deposit-forming tendency of an automotive spark-ignition engine fuel.

5.1.2 *Relevance of Results*—The operating conditions and design of the laboratory apparatus used in this test method may not be representative of a current vehicle fuel system. These factors must be considered when interpreting results.

5.2 *Test Validity:*

5.2.1 *Procedural Compliance*—The test results are not considered valid unless the test is completed in compliance with all requirements of this test method. Deviations from the parameter limits presented in Section 10 will result in an invalid test. Engineering judgment shall be applied during conduct of the test method when assessing any anomalies to ensure validity of the test results.