Designation: D5598 – 18

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

This standard is issued under the fixed designation D5598; 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.

INTRODUCTION

This test method is based on a test procedure developed by the Coordinating Research Council (CRC) and maintains as much commonality as possible with the original test. A similar test method is described in the California Air Resource Board (CARB) report, "Test Method for Evaluating Port Fuel Injector Deposits in Vehicle Engines."

Driveability problems in PFI automobiles were first reported in 1984. These driveability problems were caused by deposits in the tips of pintle-type fuel injectors. In response to this problem, the CRC developed a program to evaluate a method of testing PFI deposit-forming tendencies in gasolines. D235-h test cycle consisting of 15 min of operation at 88 kph (55 mph) followed by a 45 min soak period was used for the program. This test cycle showed statistically significant differences in deposit-forming tendencies of the test fuels on the vehicles' fuel injectors. The results of the CRC program are discussed in CRC Report No. 565,[2] and SAE Paper 890213.[3]

1. Scope*

1.1 This test method covers a vehicle test procedure to evaluate the tendency of an unleaded spark-ignition engine fuel to foul electronic port fuel injectors (PFI).

1.2 The test method is applicable to unleaded spark-ignition engine fuels which may contain antioxidants, corrosion inhibitors, metal deactivators, dyes, deposit control additives, and oxygenates.

1.3 The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information only.

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 D5598, contact ASTM 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:*[4]

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

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

[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 Dec. 1, 2018. Published December 2018. Originally approved in 1994. Last previous edition approved in 2012 as D5598 – 01 (2012). DOI: 10.1520/D5598-18.

[2] CRC Report No. 565 "A Program to Evaluate a Vehicle Test Method for Port Fuel Injector Deposit-Forming Tendencies of Unleaded Base Gasolines," February 1989. Available from Coordinating Research Council, Inc., 5755 North Point Parkway Suite 265 Alpharetta, GA 30022, www.crcao.org.

[3] Tupa, Taniguchi, Benson, "A Vehicle Test Technique for Studying Port Fuel Injector Deposits—A Coordinating Research Council Program," Society of Automotive Engineers (SAE) Technical Paper Series: Paper No. 890213, 1989, Available from Society of Automotive Engineers International, 400 Commonwealth Dr., Warrendale, PA 15096.

[4] 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.

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

Automotive Spark-Ignition Engine Fuel for Intake Valve Deposit Formation

2.2 *ANSI Standard:*[5]

MC 96.1 Temperature Measurement Thermocouples

2.3 *Other Standards:*

"Test Method for Evaluating Port Fuel Injector (PFI) Deposits In Vehicle Engines," State of California—Air Resources Board (CARB), Stationary Source Div., March 1, 1991 (incorporated by reference in California Code of Regulations, Title 13, Section 2257).[6]

Title 1—Provisions for Attainment and Maintenance of National Air Quality Standards, Clean Air Act Amendments of 1990 Public Law 101-549, Nov. 15, 1990.[7]

3. Terminology

3.1 For general terminology, refer to Terminology D4175.

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 *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**

3.2.2.1 *Discussion*—The performance characteristics may include cold starting and warm-up, acceleration, idling, and hot starting

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *deposit control additive, n*—material added to the base fuel to prevent or remove deposits in the entire engine intake system.

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

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*—needle-like metering device, 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 which is used to accumulate mileage 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 port fuel injectors of a modern spark-ignition engine. This test method described herein utilizes a 2.2 L Chrysler turbocharged engine equipped with an overhead camshaft, two valves per cylinder, and electronic port fuel injection. This test method includes a procedure for running a vehicle on a prescribed test cycle to form deposits in the port fuel injectors and a procedure for determining the resultant flow loss of a set of standardized injectors of known flow rate.

4.2 Each test begins with a new set of standardized fuel injectors which have previously been flow rated. All routine maintenance is performed in accordance with the Chrysler service manual.[8] The entire fuel system is flushed and filled with the new test fuel. To ensure compliance with the established test procedure, a data logger is active at all times after the test has begun, during all mileage accumulation and soak times.

4.3 The vehicle is operated on a cycle consisting of 15 min at a speed of 88 kph (55 mph) and an engine soak time of 45 min. This cycle is repeated for a total of 16 100 km (10 000 miles).

4.4 After the required mileage has been accumulated, the port fuel injectors are removed from the engine and the end-of-test flow rate is measured. The resultant flow loss is then calculated by comparing both end and start of test flow rates. Operational and mechanical criteria are then reviewed to determine if the test shall be considered valid.

5. Significance and Use

5.1 *Test Method*—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, loss of power, or a combination thereof, that are easily noticed by the average driver and 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 design, port fuel injector design, and composition of fuel used. The procedure in this test method has been found to build deposits in injectors on a consistent basis. The deposits formed by this procedure are similar to the deposits experienced in the field in terms of composition and in amount of deposition. This procedure can be used to evaluate differences in unleaded base fuels and fuel additives.

5.1.1 *State and Federal Legislative and Regulatory Action*—Legislative and regulatory activity, primarily by the state of California[6] and the Federal Government[7] necessitate

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

[6] Available from California Air Resources Board, P.O. Box 2815, Sacramento, CA 95812, http://www.arb.ca.gov.

[7] Clean Air Act Amendments of 1990, Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

[8] Available from Chrysler Corp. Service Publications, 25999 Lawrence Ave., Center Line, MI 48015.

TABLE 1 Allowable Vehicle List

Chrysler	Dodge	Plymouth
Laser	Daytona	Caravelle
LeBaron	600	Lancer
LeBaron GTS	Charger	Sundance
New Yorker	Shadow	Omni GLH

TABLE 2 Frequently Replaced Parts List

Part	Part No.
Air conditioning belt	4343523
Air filter	4342801
Distributor cap (1987)	5226546
Distributor rotor (1987)	5226535
Exhaust pipe hanger	4150798
Fan relay package	4419169
Fuel injector	4306024
Fuel injector O-ring	5277919
Oil filter (1986)	4419970
Oil filter (1987)	4105409
Oxygen Sensor	5227368
Positive crankcase ventilation (PCV) hose	4387387
Positive crankcase ventilation (PCV) valve (1987)	3671076
Power steering belt	4343490
Radiator cap	3781830
Spark plug	RN12YC[A]
Spark plug wires	4419359
Temperature sensor	5226374
Timing chain cover	4105714
Voltage regulator	4275313
Water pump	4293898
Water pump with O-ring	5203542
Fuel pressure regulator	4275313

[A]Champion, or equivalent.

the acceptance of a standard test method to evaluate the port fuel injector deposit-forming tendency of an automotive spark-ignition engine fuel.

5.1.2 *Relevance of Results*—The operating conditions and design of the engine and vehicle used in this test method are not representative of all modern automobiles. These factors must be considered when interpreting test 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 a void test. Engineering judgment must be applied during conduct of the test method when assessing any anomalies to ensure validity of the test results.

5.2.2 *Vehicle Compliance*—A test is not considered valid unless the vehicle has met the quality control inspection requirements in accordance with 8.2.

6. Apparatus

6.1 *Automobile*—The vehicle to be used for this test method is a Chrysler Corp. vehicle equipped with a 2.2 L, 4-cylinder turbocharged engine. An intercooled turbocharged engine may also be used. Vehicles equipped with either manual or automatic transmissions are acceptable. Hood vents shall be plugged on vehicles so equipped. Only vehicles from model years 1985 through 1987, inclusive, shall be used. Allowable vehicle models are shown in Table 1.

6.1.1 *Electronic Port Fuel Injectors*— Only Bosch EV1.1A pintle-style injectors with plastic caps shall be used. These injectors are Bosch part number 0280150360.[9] The corresponding Chrysler Corp. part number is 4306024 and is clearly marked on the injector. All tests shall begin with new, flow-tested injectors. Each new injector shall be qualified for leak rate prior to testing using the procedure in Annex A1.

6.1.2 *Tires*—All tires shall be of the same size and as specified by the vehicle manfacturer. Tires shall be inflated to the manufacturer's recommended pressure or up to a maximum pressure of 310 kPa ± 10 kPa (45 psi ± 0.5 psi) for chassis dynamometer use.

6.1.3 *Miscellaneous Parts*—All powertrain components, front-end accessory drive, air intake system, and exhaust system, except as specified, shall be original equipment, original equipment manufacturer replacement parts, or equivalent.

6.1.4 *New Engine/Vehicle Parts List*—Table 2 contains those frequently replaced parts with the corresponding Chrysler/Mopar part number to be used for the buildup of the vehicle as required by this test method. Part numbers suggested in Table 2 or listed by the manufacturer may vary from model-to-model.

6.2 *Laboratory Facilities:*

6.2.1 *Fuel Injector Testing Area*—The ambient atmosphere of the fuel injector testing area shall be reasonably free of contaminants. The temperature shall be maintained at a uniform temperature between 21 °C and 27 °C (70 °F and 80 °F). Uniform temperature is necessary to ensure repeatable injector flow measurements. (**Warning—**Provide adequate ventilation and fire protection in areas where flammable or volatile liquids, or both, and solvents are used. Suitable protective clothing is recommended.)

6.2.2 *Garage/Maintenance Area*—The ambient atmosphere of the garage/maintenance area shall be reasonably free of contaminants. The temperature and humidity shall be maintained at a uniform, comfortable level. Because of the delicate nature of the deposits, do not subject the deposits to extreme changes in temperature or humidity. (**Warning—**Adequate ventilation and fire protection are necessary in areas where automotive spark-ignition engine fuel and deposit control detergent additives are handled. Suitable protective clothing is recommended.) (**Warning—**Adequate ventilation and fire protection are necessary concerning the venting of the vehicle exhaust and when working on vehicle fuel systems. Suitable protective clothing is recommended.)

6.2.3 *Chassis Dynamometer*—A chassis dynamometer may be used for mileage accumulation. The dynamometer shall be calibrated before the beginning of each series of tests and monitored throughout each test. Both single- and dual-roll dynamometers are acceptable for use.

6.2.4 *Deposit Control Additive Blending Facilities*—Instead of supplying a finished test fuel, the test sponsor may supply concentrated additive in bulk to the test laboratory. The test requestor shall obtain concurrence from the test laboratory regarding the supply of base fuels and additives and their

[9] Available from Robert Bosch Corp., 2800 S. 25th Ave., Broadview, IL 60153.

packaging. For those laboratories offering the capability of blending additive and base fuel, the laboratories must have the ability to handle and blend the additive into fuel supplied in either bulk, 210 L (55 gal) drums, or both. The laboratory shall have an appropriate balance or graduated cylinder to blend the additive at the recommended concentrations expressed as a mass or volumetric ratio. The base fuel and additive shall be placed, at the appropriate ratio, into 210 L drums or bulk storage tanks and clearly labeled. Provisions to stir or recirculate the fuel/additive blend to ensure a homogeneous mixture are necessary. Safe, clean storage shall be provided for base fuel, additive, and test fuel. The ambient atmosphere of the additive blending facility area shall be reasonably free of contaminants. The testing laboratory shall retain a 1 L sample of the fuel blend. The sample shall be held for one month after test completion date or released to test requestor. (**Warning—** Adequate ventilation and fire protection are necessary in areas where automotive spark-ignition engine fuel and deposit control detergent additives are handled. Suitable protective clothing is recommended.)

6.2.5 *Fuel Storage and Refueling Facilities*—Sufficient finished test fuel shall be stored at the refueling station in clearly labeled drums or dispensers. In laboratories that may run several different test methods concurrently, dispensers or hand pumps for the drums shall not be switched between dissimilar test fuels. To ensure the test fuels are not contaminated either by other test fuels or foreign matter, a suitable structure shall be provided to contain the test fuels safely. The laboratory shall have a protocol to ensure the test vehicle receives the proper test fuel. (**Warning—**Adequate ventilation and fire protection are necessary in areas where automotive spark-ignition engine fuel and deposit control detergent additives are handled. Suitable protective clothing is recommended.) (**Warning—** Adequate ventilation and fire protection are necessary concerning the venting of the vehicle exhaust and when working on vehicle fuel systems. Suitable protective clothing is recommended.)

6.3 *Laboratory Equipment:*

6.3.1 *Data Acquisition*—A data acquisition device, capable of collecting the raw data in accordance with 10.5, shall be required.

6.3.2 *Temperature Measurement Equipment*— Temperature measurement equipment and locations for the required temperature measurements are specified as follows. Alternative temperature measurement equipment may be used if equivalent performance can be demonstrated. The accuracy and resolution of the temperature measurement sensors and the complete temperature measurement system must follow guidelines detailed in the Research Reports "Data Acquisition Task Force Report"[10] and "Instrumentation Task Force Report to ASTM Technical Guidance Committee."[11]

6.3.2.1 If thermocouples are used, all thermocouples shall be premium, sheathed types. Thermocouples, wires, and extension wires should be matched to perform in accordance with the limits of error as defined by ANSI MC96.1. Either Type J (Iron-Constantan), Type T (Copper-Constantan), or Type K (Chromel-Alumel) thermocouples are acceptable.

6.3.3 *Vehicle Speed*—A suitable sensor shall be utilized to measure vehicle speed ±2 kph (±1 mph).

6.3.4 *Engine On-Time*—A suitable means shall be utilized to record ignition power on and off time during each 1 h cycle, accurate to the nearest second.

6.4 *Special Measurement and Assembly Equipment:*

6.4.1 *Graduated Cylinder*—Blending of the additive may be required and the concentration may be given as a volumetric ratio (see Note 2). A1000 mL graduate is recommended.

NOTE 2—Volumetric measurement of the deposit control additive is not recommended. Mass-based measurement is preferred.

6.4.2 *Analytical Balance*—Blending of the additive may be required and the concentration may be given as a mass ratio. An analytical balance capable of a 0.01 g resolution with a maximum capacity of at least 2000 g is recommended. The balance shall be calibrated following the manufacturer's procedure and frequency recommendations.

6.4.3 *Fuel Injector Flow Apparatus*—A suitable fuel injector flow measurement device shall be capable of accurate, repeatable flow measurements. The injector flow apparatus shall maintain a constant flow fluid temperature between 21 °C to 27 °C (70 °F to 80 °F) and shall be recorded for each set of injector flow measurements. The maximum deviation in temperature between injector flow measurements throughout an entire test shall be less than 5 °C (9 °F). Be aware that temperature affects a fluid's volume and density and use engineering judgment along with good laboratory practices to enable a high level of test precision and accuracy. The test fluid pressure supplied to the injector(s) shall be 310 kPa ± 3.4 kPa (45 psi ± 0.5 psi) during the entire test. Maintaining this pressure is very critical because a small change in pressure will have a dramatic effect on the flow rate and spray pattern. Either a direct weight or volumetric measurement technique is acceptable for quantifying fuel injector flow rates. An illustration of a fuel injector flow apparatus is shown in Fig. 1. Necessary requirements of any type of flow bench design include the following:

6.4.3.1 *Fluid Flow Measurement Device*— The device shall have ±0.5 mL accuracy.

6.4.3.2 *Timer Mechanism*—The device shall be capable of ±0.01 s accuracy.

6.4.3.3 *Analytical Balance*—If a direct weigh method is utilized, an analytical balance shall be used with a 600 g capacity or higher, and ±0.001 g resolution.

6.4.3.4 *System Fuel Pump*—The fuel pump shall be capable of supplying a fuel pressure of 375 kPa (55 psi). Pump shall be compatible with fuel pressure regulator (see also 6.4.3.8 for requirements).

6.4.3.5 *System Fuel Filter*—Chrysler part number 4279987, or equivalent, shall be used.

[10] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1210. Contact ASTM Customer Service at service@astm.org.

[11] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1218. Contact ASTM Customer Service at service@astm.org.

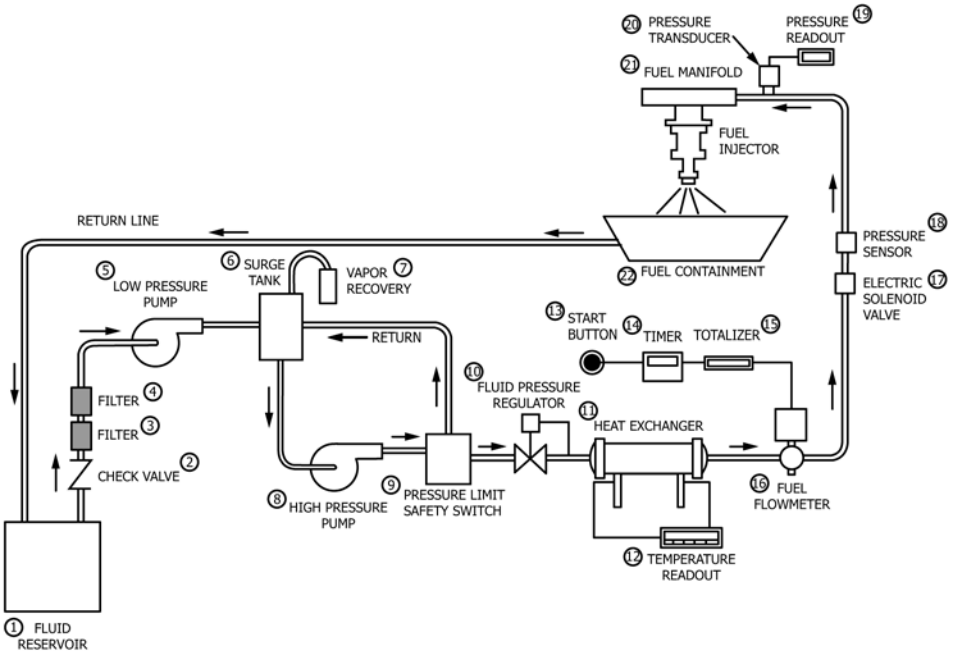

FIG. 1 Fuel Injector Flow Apparatus (example)

6.4.3.6 *Power Supply*—An electronically controlled 12 V d-c device shall be used to energize injectors. Batteries shall not be utilized to energize fuel injectors.

6.4.3.7 *Fuel Injector Manifold*—A suitable device shall be utilized which is capable of holding one to four fuel injectors.

6.4.3.8 *Fluid Pressure Regulator*—A suitable device capable of maintaining 310 kPa ± 3.4 kPa (45 psi ± 0.5 psi) solvent pressure to injectors during injector flow testing shall be used.

6.4.3.9 *Fluid Temperature Measurement Device*—A suitable device capable of ±0.5 °C (0.9 °F) accuracy shall be used to measure solvent temperature.

6.4.3.10 *Fluid Pressure Measurement Device*— A suitable device capable of ±3.4 kPa (0.5 psi) accuracy shall be used to measure solvent pressure.

6.4.4 *Fuel Injector Leak Test Apparatus*— A suitable method to measure fuel injector leakage shall be used prior to the test to evaluate new injectors for leakage. The injector leak test stand should consist of a supply of compressed air, a fuel rail, fuel injectors, release valves, a fluid reservoir, syringes, and a pressure gage. The air shall be delivered to the fuel injectors at a minimum of 310 kPa (45 psi) to the nonenergized (closed) injector(s). Each injector tip is connected to an immersed 5 mL syringe by a length of tubing. If more than 2 mL of air leak into the syringe in a 1 min period, the injector shall be rejected for PFI testing. See Annex A1 for the injector leak test procedure and an example of a leak test apparatus.

7. Reagents and Materials

7.1 *Additive/Base Fuel*—Some test requestors may require that the test fuel be blended at the test laboratory and, therefore, will supply the deposit control additive and may, at their option or if a suitable base fuel is not available at the test laboratory, supply untreated base fuel. The test requestor shall supply the deposit control additive and, if supplied by him, the base fuel in appropriate volumes and packaging to ensure safe and efficient handling. Blending instructions detailing the concentration ratio either volumetric-based or mass-based shall accompany all deposit control additives. Mass-based measurement is preferred. However, it is most desirable to have the additive supplied in premeasured, individual containers. The blended fuel shall be clearly identified.

7.1.1 *Additive/Base Fuel Shipment and Storage*—The additive shall be shipped in a container as dictated by safety and environmental regulations. The additive shall be stored in accordance with all applicable safety and environmental regulations.

7.1.2 *Base Fuel*—The base fuel used for this test procedure should be typical of commercial, unleaded automotive spark-ignition engine fuel. The base fuel may contain oxygenates typical of those being used commercially. The base fuel should allow the vehicle to operate satisfactorily.

7.2 *Engine Coolant*—The coolant is a mixture of equal volumes of a commercial ethylene glycol-based antifreeze and distilled or demineralized water.

7.3 *Engine Oil/Assembly Lubricant*— The standard engine oil and assembly lubricant used for all tests shall be at least of a minimum commercial quality (API SG, EC II) SAE multigrade that meets the manufacturer's recommendations.

7.3.1 *Petroleum Jelly*—A light petroleum jelly should be used as a lubricant for fuel injector installation. The petroleum jelly should be placed on the fuel injector O-ring.

7.4 *Solvents:*

7.4.1 *Flow Test Solvent*—Solvent should be isooctane of a minimum purity of 99.75 % or a mineral spirit solvent meeting Specification D235 for TYPE III or IV.

7.5 *Test Fuel*—A test fuel shall be either a base fuel or a homogeneous blend of additives and base fuel. A single batch of base fuel shall be blended before the start of the test. The fuel may be stored in drums or tankage and shall be clearly labeled to prevent misfueling. Quantities of fuel and additive blended and dispensed shall be measured and recorded. Approximately 2300 L (600 gal) of fuel are required for this test method.

7.6 Reagent grade chemicals will be used for all test procedures. Unless otherwise noted, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[12] Other grades may be used provided it is first ascertained that the reagent is of sufficient purity to permit its use without lessening the accuracy of the determination.

8. Preparation of Apparatus

8.1 *Fuel Injector Preparations:*

8.1.1 *Flush New Injectors*—New injectors shall be flushed for three 10 s intervals for a total of 30 s using flow test solvent specified in 7.4.1 to cleanse any assembly residue before flow testing.

8.1.2 *Fuel Injector Evaluation*—Prior to installation in the engine, flow rates for each injector shall be measured using flow test solvent specified in 7.4.1 and PFI spray pattern observed using a suitable apparatus as defined in 6.4.3.

8.1.2.1 *Fuel Injector Flow Measurement Procedure*—The injector flow rate data sheet (see Fig. 2) shall be used to calculate the flow rate of each injector. Three static (wide open) flow rate test trials, run for 10 s each, shall be used to calculate the average flow rate for each injector. Measure volume or mass of flow test solvent to the nearest specified unit. If additional injector flow tests are necessary (see 8.1.3.1), allow at least 10 min between successive groups of three flow measurements in order to allow the injectors to cool.

8.1.2.2 *Fuel Injector Spray Quality*—While the injector is flowing, a visual observation shall be made as to the spray pattern quality. Record this observation for each occurrence on the injector flow data sheet. Ideally the spray should be a symmetric conical shape with good atomization (see Fig. 3). There should be no *fingers* in the spray pattern. Fuel injectors shall be rejected if any spray abnormalities are encountered. Observe the test injector for at least 30 s after the power to the test injector is shut off. Any injector that drips or leaks during this period shall be rejected.

8.1.3 *Fuel Injector Acceptance Criteria*— The following guidelines shall be met when selecting injectors to be used for this test method. Groups of injectors or individual injectors not meeting the following guidelines shall not be used.

8.1.3.1 *Individual Injector Flow Repeatability Specification*—The difference between the lowest and highest of three consecutive flow tests for each fuel injector shall be no more than 1 %. If this difference between lowest and highest of three consecutive flow tests is greater than 1 %, the injector shall be flow tested three more times. If the difference between any flow rates are still larger than 1 %, the injector may be retested one more time for a total of nine flows maximum. After a potential nine flow determinations, injectors which fail to maintain a difference of less than or equal to 1 % between three successive flow rates shall be rejected for any further testing.

Vehicle No. _____ Mileage _____ Date: _____
Test Sequence _____

		INJECTOR	FLOW	TIME, sec.	TEMP.	PRESSURE	TIP/SPRAY OBSERVATION
		RUN					
TRIAL	1	1					
		2					
		3					
		4					
		RUN					
TRIAL	2	1					
		2					
		3					
		4					
		RUN					
TRIAL	3	1					
		2					
		3					
		4					
		AVG.					
		1					
		2					
		3					
		4					

FIG. 2 Fuel Injector Flow Data Sheet (example)

8.1.3.2 *Average Injector Flow Specification*—Data from a set of four fuel injectors shall be averaged. No injector average flow rate shall deviate more than 3 % from another injector average flow rate within each group of four fuel injectors. The deviation in average flow rate shall be calculated using Eq 1:

$$\text{Avg PFI Flow Deviation} = \frac{F_{\text{maxavg}} - F_{\text{minavg}}}{F_{\text{minavg}}} \times 100\,\% \qquad (1)$$

where:

F_{maxavg} = maximum value of an individual fuel injector average, and

F_{minavg} = minimum value of an individual fuel injector average.

8.2 *Vehicle Preparation:*

8.2.1 *Vehicle Break-in*—In order to ensure adequate engine and transmission break-in, the vehicle powertrain shall have a minimum of 6500 km (4000 miles) prior to the start of the test.

8.2.2 *Tires*—All vehicle tires shall be of the same size and inflated as specified by the vehicle manufacturer. For vehicles run on a chassis dynamometer, drive tires shall be inflated to 310 kPa ± 10 kPa (45 psi ± 1 psi).

[12] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.