SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Gasoline Low-Pressure Electric Fuel Pump Characterization

RATIONALE

The SAE J1537 Recommended Practice is fully revised and updated to reflect numerous changes in pump testing procedures, as well as new developments in the available technologies. Since SAE J1537 was originally published, the automotive industry has adopted new test procedures that incorporate emerging technologies and these are all incorporated in this revised document.

The use of uniform and standardized testing and evaluation procedures for in-tank fuel pumps is important to the worldwide automotive community. Standardized test procedures provide both fuel pump manufacturers and end-users with one accepted test for each of the key fuel pump performance parameters, instead of a specialized test protocol for each of many customers and applications. The use of these procedures for test configurations, testing methods, data reduction, and reporting that are contained in this document significantly enhance the ability to determine the performance, durability, and integrity of low-pressure, in-tank gasoline fuel pumps.

FOREWORD

A gasoline, low-pressure, electric fuel pump is an electrically powered and electrically controlled device that is normally used to supply pressurized gasoline to spark-ignition engines that utilize port fuel injectors (refer to SAE J1832) or as a low-pressure feeder pump to high-pressure fuel systems employing gasoline direct injectors (refer to SAE J2713). It is normally mounted in a configuration such that it is submerged in the gasoline within the fuel tank of the vehicle. Low-pressure electric pumps operate in a different manner than the high-pressure, engine-mounted pumps that are employed in gasoline direct injection (GDI) systems, hence the existing GDI pump recommended practice (refer to SAE J2714) cannot be employed. These tests that are detailed in this recommended practice will permit the evaluation, characterization and comparison of in-tank, low-pressure electric fuel pumps. It should be noted that such pumps that are manufactured as components in a fully contained fuel-supply module may not be amenable to testing using some of the listed test procedures.

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1. SCOPE

This SAE Recommended Practice defines the tests for three basic categories of pump characteristics. These are the basic functional performance tests, the pump limitation tests and the pump integrity tests. The basic functional tests included are three individual tests, with the first being for pump speed, current draw, and electrical resistance. The other two individual tests are for the deadhead pressure and the delivered fuel flow rate at the rated delivery pressure and voltage. The included tests for pump limitations are individual tests for hot fuel handling, cold magnet knockdown, load dump transient, electrical interference, and reverse flow leak. The testing for pump integrity includes individual tests for vibration, temperature cycling, internal fluid compatibility, and operational durability. These 12 individual tests provide a characterization of the particular pump. This document only addresses the in-tank-mounted, electric-motor-driven, low-pressure fuel pump itself, and does not address in-tank pump modules, as these modules may include other devices. The pumps that are to be tested are intended for the pumping of liquid fuels that are applicable to fuel-injected, spark-ignition engines.

1.1 Purpose

The purpose of this recommended practice is to provide a neutral, unbiased test for each defined performance parameter of the gasoline, low-pressure, electric fuel pump. The specific purposes of the SAE J1537 document are to:

- Standardize the use of nomenclature specifically related to the performance evaluation and characterization of the gasoline, low-pressure, electric fuel pump.
- Identify and define the key metrics that constitute the characterization of this type of pump.
- Establish detailed test procedures and recommend test equipment and methods to measure these key metrics.
- Establish the recommended data reduction and analytical procedures associated with the defined tests.
- Establish the criteria for data reporting and the required accompanying information that must be reported in order to interpret and reproduce the test results and compare one pump to another.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J1113/11 Immunity to Conducted Transients on Power Leads

SAE J1681 Gasoline, Alcohol, and Diesel Fuel Surrogates for Materials Testing

SAE J1747 Recommended Methods of Conducting Corrosion Tests in Hydrocarbon Fuels or Their Surrogates and Their Mixtures with Oxygenated Additives

SAE J1832 Low Pressure Gasoline Fuel Injector

SAE J2713 Direct Injection Gasoline Fuel Injector Characterization

SAE J2714 Gasoline Direct Injection Pump

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM D86 Standard Test Method for Distillation of Petroleum Products

ASTM D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)

ASTM D1266 Test Method for Sulfur in Petroleum Products (Lamp Method)

ASTM D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption

ASTM D2699 Standard Test Method for Research Octane Number of Spark Ignition Engine Fuel

ASTM D3231 Test Method for Phosphorus in Gasoline

ASTM D3237 Test Method for Lead in Gasoline by Atomic Absorption Spectrometry

ASTM D4806 Standard Specification for Denatured Fuel Ethanol for Blending with Gasolines for Use as Automotive Spark Ignition Fuel

ASTM D4814 Standard Specification for Automotive Spark Ignition Engine Fuel

2.1.3 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

40 CFR 86.113-04 Test Fuel Specifications without Ethanol

2.1.4 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/.

ISO 7637-2 (2011) Road Vehicles - Electrical Disturbances from Conduction and Coupling - Part 2: Electrical Transient Conduction Along Supply Lines Only

3. DEFINITIONS

3.1 INDOLENE UNLEADED GASOLINE

Gasoline as defined in the Code of Federal Regulations, Title 40, Part 86, Section 113. See Appendix A for details. See 4.1 for the use of alternative test fluids.

3.2 RETURN PRESSURE (P_{ret})

The pressure in the return fuel line back to the fuel tank in a return-type system. Returnless fuel systems do not have this line. The pressure is expressed in kilopascals (kPa).

3.3 PUMP OUTLET PRESSURE (P_{out})

The fuel pressure supplied by the pump, as measured at the pump outlet. This is expressed in kilopascals (kPa).

3.4 NORMAL OPERATING PRESSURE (P_{NORM})

The normal operating pressure is the average pressure to which the pump will be commanded during normal operation, and is used to establish the pump dynamic characteristics. P_{NORM} is established by the application and is equal to or higher than the application system pressure at the engine. The normal operating pressure is expressed in kilopascals (kPa).

3.5 MAXIMUM OPERATING PRESSURE (P_{max})

The maximum pressure to which the pump assembly will be subjected, including momentary surges in pressure which may occur during normal service. The maximum operating pressure is expressed in kilopascals (kPa). This is also referred to as the maximum working pressure

3.6 DEADHEAD PRESSURE (P_{dh})

The test pressure that is generated by the pump when the outlet of the pump is totally blocked. The deadhead pressure is expressed in kilopascals (kPa). A typical value of P_{dh} is approximately 900 kPa.

3.7 PRESSURE FLUCTUATION PEAK-TO-PEAK (P_{p-p})

The maximum fluctuation of fuel pressure at the pump outlet that is measured while operating at a specified operating condition. This is the difference between the maximum and minimum instantaneous pressure values as observed over a minimum of ten full pump cycles and is expressed in kilopascals (kPa).

3.8 PUMP DISPLACEMENT (VD)

The displacement of the pump is the theoretical volume displaced per drive shaft revolution. The displacement is dependent only upon the physical dimensions of the pumping elements. It is a volume that is expressed in liters (L).

3.9 PUMP SPEED (N_p)

The speed of the pump as indicated by the number of revolutions per minute (rpm) of the pump drive shaft.

3.10 PUMP MAXIMUM SPEED (N_{max})

The maximum speed of the pump that is attainable without sustaining permanent damage. It is expressed in revolutions per minute (rpm)

3.11 PUMP CAPACITY (Q_p)

The pump capacity is the quantity of fluid actually delivered per unit of time, including both liquid and any dissolved or entrained gases, under specified operating conditions. It is measured in units of liters per hour (L/h).

3.12 PUMP DELIVERED FUEL FLOW RATE (Q_d)

The pump delivered fuel flow rate is the rate of fuel delivered for operation at standard test conditions using the standard test fuel of Indolene unleaded gasoline and at the rated delivery pressure of the application pump being tested. It is measured in units of liters per hour (L/h).

3.13 PUMP VOLUMETRIC EFFICIENCY (η_V)

The pump volumetric efficiency is the ratio of the pump capacity (Q_p) divided by the pump displacement (VD) for a specified operating condition. The volumetric efficiency is expressed as a percentage (%).

3.14 PUMP OVERALL EFFICIENCY (η)

The pump overall efficiency is the ratio of the pump output power (as determined from the flow and pressure measurements) to the pump input power (as determined from the voltage and current at the pump electrical terminals). The pump overall efficiency is expressed as a percentage (%).

$$\eta = [(\text{Flow rate}*\text{Pressure})/(3600*\text{Voltage}*\text{Current})] * 100\% \quad \text{(Eq. 1)}$$

Where the associated units are flow rate (L/h), pressure (kPa), voltage (VDC), and current (A).

3.15 PUMP TIME-TO-PRIME (t_{prime})

The pump time-to-prime is the time between the initial application of pump voltage and the attainment of 75% of the pump's rated pressure in the fuel line at the outlet of the pump.

4. STANDARD TEST CONDITIONS

The following standard test conditions are recommended:

4.1 Test Fluid

Indolene unleaded gasoline is specified as the standard test fluid for the measurement of pump performance characteristics unless otherwise specified for a particular test. The detailed specifications for this test fluid are provided in Table A1 in Appendix A. For any testing at elevated temperatures (above 35 °C), the specified test fluid shall be Bogey II. For example, the fuel temperature exceeds 60 °C in the hot fuel handling test. The specifications for Bogey II are also listed in Appendix A.

It is important to note that alternate test fluids to Indolene unleaded gasoline, such as MIL-PRF-7024 Type II laboratory test fluid (Stoddard solvent calibration fluid), mineral spirits, and other fluids which have properties approximating the physical properties of Indolene unleaded gasoline may be utilized without creating a test deviation. The use of one of these fluids is sometimes required for safety reasons in certain laboratory installations, and such usage is fully described in SAE J1681. However, if Indolene unleaded gasoline is not used as the test fluid when that test calls for it, the actual test fluid is to be clearly indicated on the data-reporting sheet. If the actual alternate fluid used is not Stoddard solvent or mineral spirits, then a listing of the physical properties of the actual fluid used shall be attached to the data-reporting sheet for that test. It should also be noted that some pump tests (such as pump durability) will require special specific corrosive fluids other than Indolene unleaded gasoline. If the test being conducted requires a specific fluid other than Indolene unleaded gasoline, then the non-use of Indolene unleaded gasoline does not have to be called out on the data reporting sheet.

4.2 Test Fluid Temperature

The test fluid temperature shall be measured at the pump inlet and is to be stabilized at 21 °C ± 2 °C, unless otherwise specified in a particular test.

4.3 Pump Inlet Pressure

The average gauge pressure measured at the inlet to the pump. Pump inlet pressure shall be held to ±2% of the set value throughout the test, unless otherwise specified.

4.4 Pump Outlet Pressure

The average gauge pressure measured at the pump outlet. Pump outlet pressure shall be held to ±2% of set value throughout the test, unless otherwise specified.

4.5 Ambient Test Conditions

Unless otherwise specified for a specific test, the ambient air temperature should be maintained at a temperature of 21 °C ± 2 °C and within a pressure range of 100 kPa ± 5 kPa.

5. EQUIPMENT REQUIRED FOR FUEL PUMP TESTING

This section describes the test equipment and configurations that are necessary for the measurement of fuel pump functionality, durability and integrity.

5.1 General Fuel Pump Test Equipment (see Figure 1)

This section describes the basic equipment and interconnection considerations required to obtain flow performance data from the various test configurations. The basic performance test equipment shall be capable of adjusting the voltage that is applied to the pump, the test fluid pressure, and of using a range of test fluids at controlled temperatures. The equipment shall also be capable of monitoring and measuring the following pump flow parameters:

- Pump delivered flow rate
- Pump current draw
- Pump operating pressure
- Pump voltage
- Pump speed

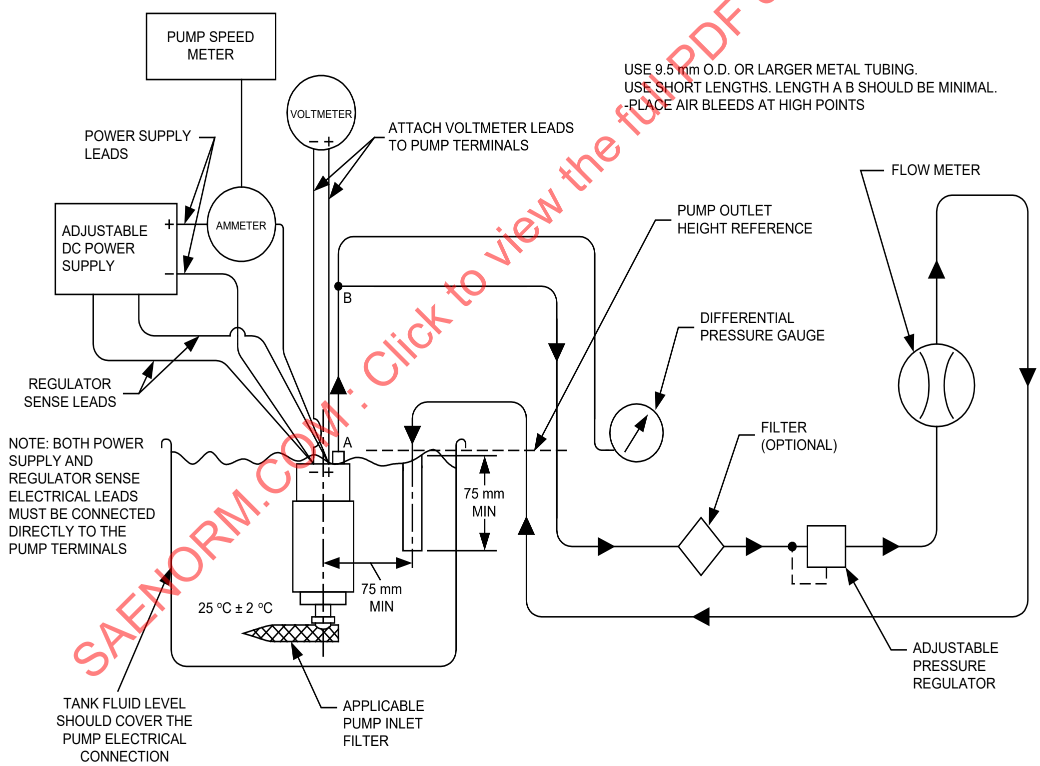

Figure 1 - Schematic of the flow test stand configuration for electric fuel pump testing

5.1.1 Adjustable DC Power Supply

a. Voltage range: 0 to 24 VDC.

b. Current range: 0 to 50 A (minimum).

c. Stability: Must maintain set voltages at the pump terminals during flow measurement within ±0.1 V.

NOTE: A power supply with external voltage sense capability allows the power supply to sense and stabilize the voltage at the pump terminals.

5.1.2 DC Ammeter

a. Current range: 0 to 50 ADC.

b. Accuracy: ±0.01 A.

5.1.3 DC Voltmeter

a. Voltage range: 0 to 24 VDC.

b. Accuracy: ±0.01 V.

c. Connection: Voltmeter leads are to be connected directly to pump terminals (see Figure 1).

5.1.4 Pressure Measurement (Transducer, Gage, or Manometer)

a. Pressure ranges:

   1. 0 to 1000 kPa.

   2. Higher pressure ranges may be required depending on the pump type and application.

b. Accuracy: ±1% of reading.

c. Location: The differential transducer or gage must be referenced to the same level as the pump outlet (see Figure 1).

5.1.5 Pump Speed Monitoring and Measurement

a. Speed range: 0 to 20000 rpm.

b. Accuracy: ±1% of reading.

c. Measurement method: Measure frequency of current ripple.

5.1.6 Filter (Optional)

A maximum pressure differential for the filter should be 5 kPa at a flow rate of 600 L/h. The filter should contain an air bleed or have a configuration which eliminates trapped air.

5.1.7 Adjustable Flow Restrictor or Pressure Regulator

The maximum pressure differential with the restrictor wide open should be 7 kPa at a flow rate of 200 L/h. The maximum restriction may be fully closed.

5.1.8 Flowmeter

- Range: 0 to 600 L/h.
- Accuracy: ±0.5% of full scale, with test fluid outlined in 4.1.

5.1.9 Tubing

- Size: 9.5 mm OD (minimum).
- Length: As short as possible.
- Bends: None preferable.
- Material: Stainless steel.

5.1.10 Test Fluid Reservoir Tank

The test fluid reservoir tank shall be stainless steel. The height of the tank shall be sufficiently high such that the test fluid covers the electrical connection of a vertically mounted fuel pump, and shall be sufficiently wide such that the fluid return tube can be at least 75 mm from the pump inlet.

5.2 Specific Equipment for Individual Pump Tests

The special test equipment that is specific to each individual test within the document is described in this section. This includes specialized test equipment, facilities (such as explosion-proof), special test fluids, as well as specialized drain and submersion tanks.

5.2.1 Hot Fuel Handling Test Equipment

A special test stand capable of operation using Bogey II test fluid at elevated fluid temperatures of up to 70 °C is required. A schematic of this type of stand is illustrated in Figure 2. This stand must also be in an explosion-proof room that is rated as NEC Class 1, Division 1, Group D. The stand is to have the capability of monitoring and measuring the pump speed and fluid pressure, and of applying and monitoring the DC voltage applied to the electrical connectors of the pump. A sealed stainless steel tank with a volume of at least 20 L is required.

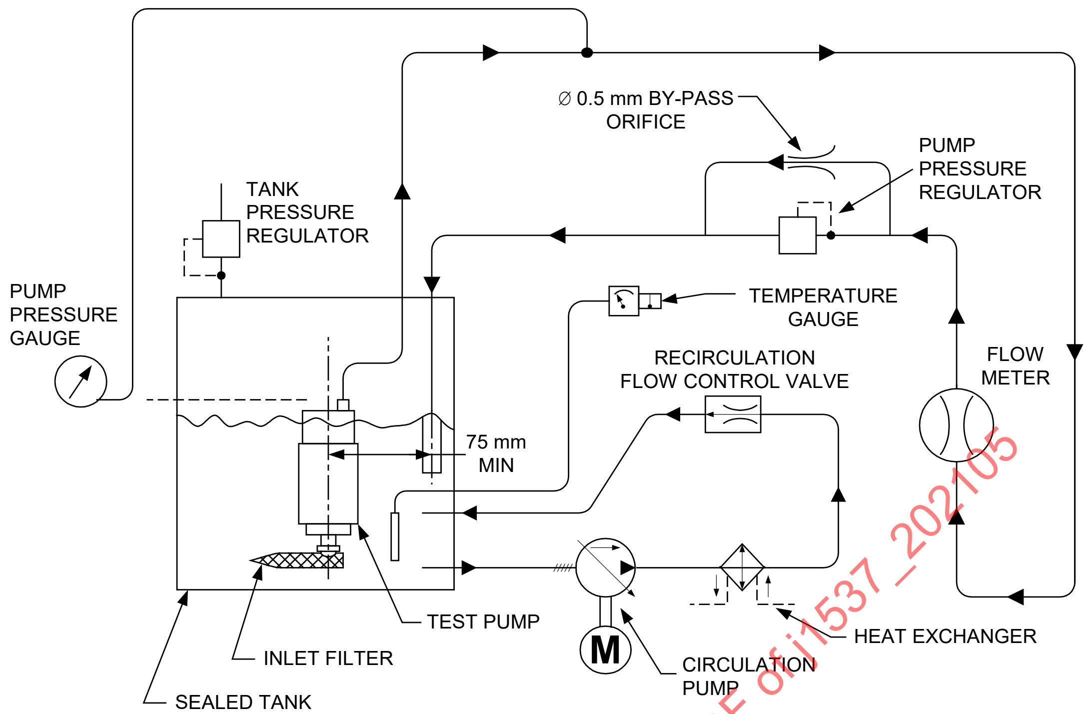

Figure 2 - Schematic of equipment for the hot fuel handling test

5.2.2 Cold Magnet Knockdown Test Equipment

A sealable stainless steel tank capable of immersing at least five pumps in Indolene unleaded gasoline is required. A cooling system capable of lowering the fluid temperature to at least -40 °C and maintaining a temperature of this order for up to 150 minutes is also required. A voltage controller and a wiring harness capable of energizing at least five pumps with 24 VDC is also required.

5.2.3 Load Dump Transient Test Equipment

Refer to SAE J1113/11 for a listing of the equipment required for this test.

5.2.4 Test Equipment for the Optional Electrical Interference Test

Refer to ISO 7637-2 (2011) for the equipment required for this test.

5.2.5 Deadhead Pressure Test Equipment

A standard test stand capable of operation using Indolene unleaded test fluid is required. The stand is to have the capability of monitoring and measuring the pump speed and fluid pressure, and of applying and monitoring the DC voltage applied to the electrical connectors of the pump. In addition, a specially designed sealing plate is needed to block all pressurized fluid from exiting the standard outlet of the pump. Part of the design of this sealing plate is to incorporate a pressure-monitoring port at the plane of the pump outlet. A fuel collection line or tube is required in order to convey waste fuel from the pump pressure-relief valve back to the fluid reservoir or to a waste collection tank.

5.2.6 Reverse Flow Leak Test Equipment

A test fixture similar to that shown schematically in Figure 3 is required to conduct the reverse flow leak test. A stainless steel supply tank for Indolene unleaded gasoline is part of the test fixture, as is a standard bottle of dry nitrogen and a burette that is calibrated in milliliter divisions. The burette must be capable of safely sustaining an internal pressure level of 1040 kPa without damage when the end of the burette is sealed and internal pressure is applied.

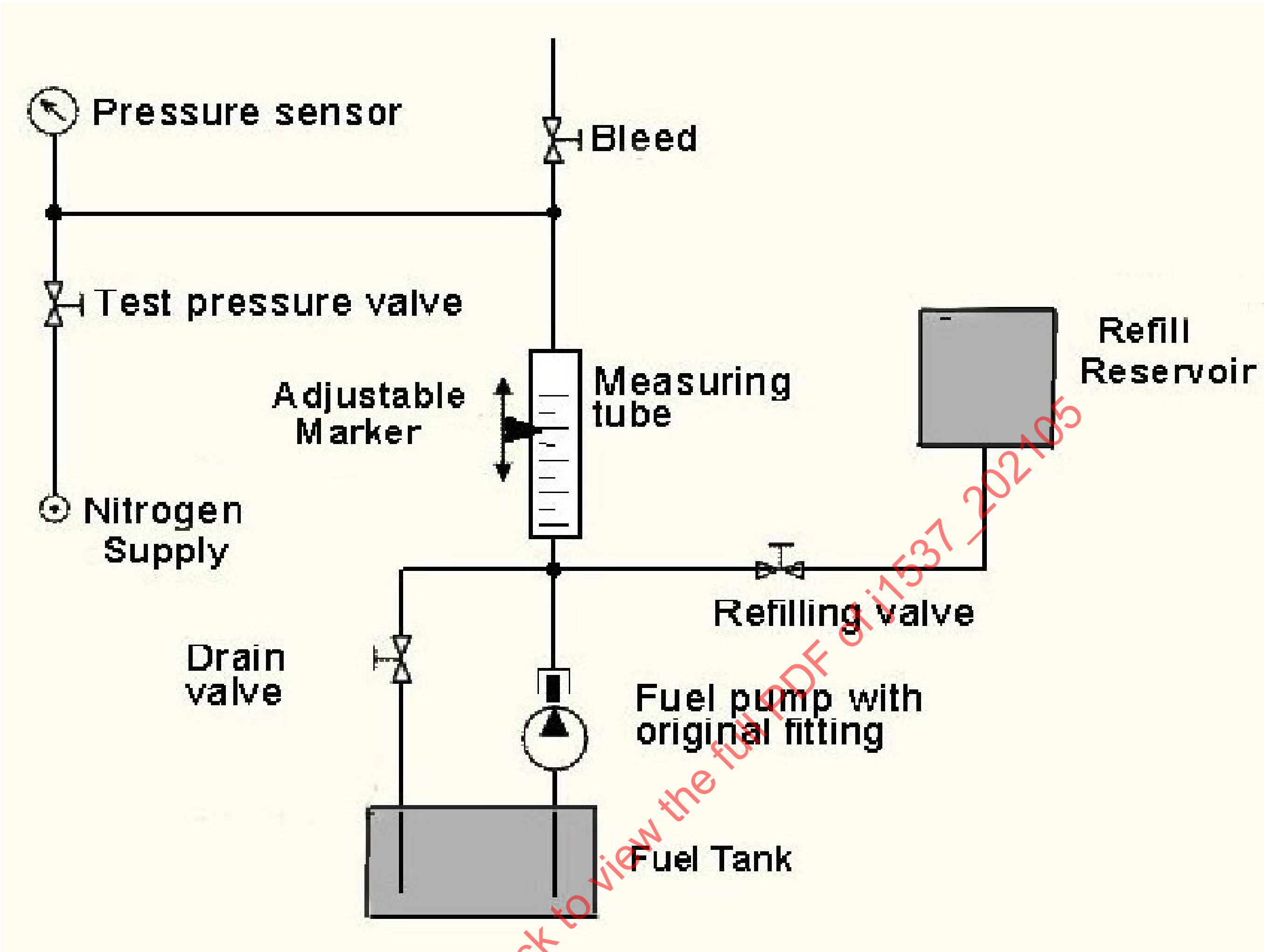

Figure 3 - Schematic of the test fixture for determining the reverse flow leakage

5.2.7 Vibration Test Equipment

A standard commercial vibration shaker table is required to conduct the vibration test. This shaker table should ideally have the capability of mounting five in-tank pumps at the same time, but a table that can mount only one pump is acceptable. The associated diagnostic electronics for the table shall be capable of measuring the vibration frequency, amplitude, and acceleration in each of three different orthogonal orientations of the axis.

5.2.8 Temperature Cycling Test Equipment

Two thermal chambers are required for this test, each with a volume capable of accommodating at least five pumps simultaneously. One is a heating chamber and the other is a cooling chamber. The heating system must be capable of maintaining the air in the heating chamber at 80 °C for at least 6 hours. Similarly, the cooling system for that chamber must be capable of maintaining the air temperature in the cooling chamber at -35 °C or below for at least 6 hours. The palette containing the test pumps may be moved manually from one chamber to the other, or commercial automated equipment may be employed to accomplish this. No electrical equipment is required, as the pumps are not energized.

5.2.9 Internal Fluid Compatibility Test Equipment

A stainless steel containment vessel (minimum grade is type 304) is required to conduct the internal fluid compatibility test. The vessel shall be capable of holding at least five in-tank pumps simultaneously and should be leak-proof regarding all of the range of immersion test fluids that are specified in the test. It should also have a sealable access door or cover. Multiple such vessels are required if multiple immersion test fluids are to be tested simultaneously. A single voltage controller set for 12.0 VDC and a single pump wiring connector are the only electrical components required.

5.2.10 Operational Durability Test Equipment

A stainless steel containment vessel with a volume of at least 54 L is required to conduct the operational durability test. A durability test stand capable of accommodating multiple pumps in each run (preferably a minimum of five) is also required. This stand should have the capability of running gasoline, E85, and a corrosive mixture of gasoline and ethanol, and to maintain these test fluids at up to 36 °C for a period of not less than 3000 hours. The electrical power system must be capable of delivering 13.5 VDC to up to five test pumps simultaneously, and must incorporate an automated, programmable start-and-stop capability.

6. GENERAL OPERATION OF THE PUMP FLOW TEST STAND

6.1 Introduction to Pump Flow Stand Operating Considerations

An important detail in the majority of the pump tests in this document is that the five key pump performance parameters require measurements both prior to and subsequent to the running of these tests. These five parameters are the deadhead pressure, the delivered flow rate at rated pressure, the pump electrical resistance, the pump current draw, and the pump speed at the rated delivery pressure and voltage. Another key consideration is that all new pumps must be operated for an initial 10 minute break-in period prior to any testing.

6.2 Installation of Test Pumps

Each fuel pump with its appropriate inlet filter is to be installed in the test tank maintaining the conditions prescribed in Figure 1. Note particularly the position of the pressure gage in relation to the pump outlet, the point of connection for the voltmeter leads, and the position of the return line in relation to the pump and the anticipated fluid height.

6.3 Test Fluid for Pump Flow Stand Testing

Unless otherwise specified in a particular test, Indolene unleaded gasoline should be utilized as the pump test fluid. See 4.1 for a full discussion of the use of an alternative test fluid.

6.4 Adding and Maintaining the Test Fluid

The test fluid is to be added to the tank such that the pump electrical connection is covered by the fluid, and that the return line is submerged a minimum of 75 mm deep in the fluid (see Figure 1). Add any necessary test fluid throughout the test as needed to maintain that fluid level. The test fluid should be changed every 168 hours ± 8 hours to minimize the accumulation of contaminants.

6.5 General Procedure for Operating the Pump Flow Stand

a. Perform the pump break-in for each new pump that is tested by operating the pump on the standard test fluid at the rated delivery pressure. A pump break-in period of 10 minutes (or any other time period to be jointly agreed to by the manufacturer and user) should be utilized for any new pumps prior to running a performance test. Any break-in time other than 10 minutes should be indicated in the comment section of the data reporting sheet.

b. Turn on the electrical power supply and adjust the voltage to 12.0 VDC ± 0.1 VDC at the pump terminals. It should be noted that for some tests, such as operational durability, 13.5 VDC is the specified applied voltage.

c. Adjust the test stand pressure regulator to the specified operating pressure.

d. Observe the flow meter for a stable output (typically ±2%). If stable flow readings cannot be obtained, check to be sure the return line is not too close to the pump inlet (see Figure 1) and that fuel temperature is within specified limits. If instability persists, cycle the regulator several times and/or bleed the system to purge entrapped air to stabilize the flow. If the fuel flow rate is observed to be stable and the fuel temperature is within acceptable limits, proceed with the test measurements.

7. FUEL PUMP FUNCTIONAL PERFORMANCE TESTING

7.1 Introduction to Fuel Pump Functional Performance Testing

The performance testing of the in-tank, gasoline, low-pressure pump involves the measurement of five key parameters that contribute significantly to the overall performance. These five parameters are:

- Pump speed at the rated delivery pressure and voltage.
- Pump current draw.
- Pump electrical resistance.
- Deadhead pressure.
- Delivered flow rate at the rated delivery pressure and applied voltage.

The five key performance parameters are measured in three individual tests. With the pump speed at the rated delivery pressure and voltage, the pump current draw and the pump electrical resistance are measured in the first test, with the deadhead pressure and the delivered flow rate at the rated delivery pressure and voltage measured in the second and third tests, respectively. In some tests, there are additional metrics that are to be measured for the pump beyond these five key performance parameters, and these are incorporated into two additional pump test classifications of limitation testing and integrity testing. In the majority of the other nine tests described in this document, for example vibration, these five functional performance parameters in the functional performance category are to be measured both before and after the specified test in order to quantify the changes that resulted from the test. For example, the effects of vibration testing (within the integrity testing category) are ascertained by measuring the changes in the five key performance parameters that result from the test. This is accomplished by measuring the values of the five parameters before the vibration test, then measuring them again following the completion of the test.

7.2 Pump Speed, Current Draw, and Electrical Resistance Test

The functional pump speed in rpm, the pump current draw in amperes (A) and the pump electrical resistance in ohms (Ω) are to be measured while the pump is operating at the standard conditions that are defined in Section 4. The voltage applied to the pump electrical terminals shall be 12.0 VDC, and the outlet pressure shall be set to the rated delivery pressure of the pump. The parameters measured in this test comprise three of the five key performance parameters that are defined for the in-tank, low-pressure gasoline pump. These parameters are measured in many of the tests within this document, and in most cases are specified to be measured both before and after each test.

7.2.1 Procedure for the Speed, Current, and Resistance Test

a. A minimum of five new pumps are to be tested, with one pump tested at a time. More pumps may be optionally tested if desired. The pumps are to be selected from serial production. Precondition each of the test pumps by conducting a break-in procedure according to 6.5 step (a).

b. Mount a new, preconditioned test pump in a test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. Adjust the test stand pressure regulator to the rated fuel delivery pressure for the pump being tested. Operate the pump for 5 minutes at standard test conditions using the standard test fuel, with an applied voltage of 12.0 VDC ± 0.1 VDC.

c. After 5 minutes, conduct another five-minute observation run in order to monitor the pump rotor speed, the electrical current being drawn by the pump and the electrical resistance across the pump electrical connectors.

d. If the observed value of the pump speed is stable to within ±1.0% and the current draw and resistance readings are stable within ±1.5% over this 5-minute observation period, note the values.

e. If one or more parameters are observed to have fluctuations that exceed the limits in step (d), then operate the pump for an additional 5 minutes and observe and note the upper and lower limits of the fluctuating parameter, along with the mean value.

f. If additional pumps are to be optionally tested, return to step (b) and mount the next pump. Then conduct steps (c) through (f) for each remaining pump in the test set.

7.2.2 Data Reduction and Analysis for the Speed, Current, and Resistance Test

None required.

7.2.3 Data Reporting for the Speed, Current, and Resistance Test

Record the measured functional pump speed in rpm, the pump current draw in amperes (A) and the pump electrical resistance in ohms (Ω) on the data reporting sheet in Table 11. If one or more parameters were observed to be fluctuating during the observation period, record the mean value and the observed upper and lower limits.

7.3 Deadhead Pressure Test

7.3.1 Introduction to the Deadhead Pressure Test

The deadhead pressure (P_{dh}) of an in-tank, electric, low-pressure gasoline pump represents a measure of the maximum pressure that can be delivered by that pump at various applied voltages, when the pump outlet is blocked and there is zero delivered flow. It is a measure of the capability of the particular pump.

7.3.2 Procedure for the Deadhead Pressure Test

a. A minimum of five new pumps are to be tested, with one pump tested at a time. More pumps may be optionally tested if desired. The pumps are to be selected from serial production. Precondition each test pump by conducting a break-in procedure according to 6.5 step (a).

b. Mount a new, preconditioned test pump in a standard test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. Operate the pump for 5 minutes at standard test conditions using the standard test fuel and an applied voltage of 12.0 VDC, then shut off the pump.

c. Next, the pump outlet is to be blocked with a sealing plate designed to stop all fuel delivery without leakage, and also designed to provide a tap for monitoring the output fuel pressure at that plate. A capability for measuring and monitoring the stall speed of the pump rotor is also required.

d. Connect a fuel collection line and collection container to the relief valve port of the pump such that any fuel exiting the pressure relief port will be safely conducted away. This relief-valve fuel may alternatively be directed back to the test fuel reservoir in lieu of using a separate collection container.

e. The pump is then to be energized by applying 5.0 VDC ± 0.05 VDC to the electrical connectors. Allow the pump to operate for 90 seconds, then measure the pump deadhead pressure at the outlet plate. Also measure the stall speed (rpm) of the pump and the current draw (A) for this applied voltage.

f. Energize the pump again by applying 10.0 VDC ± 0.05 VDC to the electrical connectors. Allow the pump to operate for 90 seconds, then measure the pump deadhead pressure at the outlet plate. Also measure the stall speed (rpm) and the current draw (A) of the pump for this applied voltage.

g. Energize the pump for a third time by applying 12.0 VDC ± 0.05 VDC to the electrical connectors. Observe the pressure relief valve and note whether it has opened to allow fuel to escape through the collection line. Whether it has opened or not, allow the pump to operate for 90 seconds, then measure the pump deadhead pressure at the outlet plate. Also measure the stall speed (rpm) of the pump and the current draw (A) for this applied voltage.

h. If the pressure relief valve of the pump is not open at an applied voltage of 12.0 VDC, increase the applied voltage by 0.5 VDC and observe again. Continue this until either the relief valve opens or 15.0 VDC is attained without opening. It is not required to record the deadhead pressure and stall speed for intermediate applied voltages for which the pressure relief valve does not open. If the pressure relief valve opens at one of the intermediate applied voltages, allow the pump to operate for 90 seconds with the relief valve open, then measure the pump deadhead pressure at the outlet plate. Also measure the stall speed (rpm) of the pump and the current draw (A) for this intermediate voltage.

i. If 15.0 VDC is attained without the relief valve opening, allow the pump to run for 90 seconds at 15.0 VDC, then measure the pump deadhead pressure at the outlet plate. Also measure the stall speed (rpm) of the pump and the current draw (A) for this applied voltage.

j. Remove the voltage source from the electrical connectors and allow the pump to stop. Remove the test pump and replace it with the next pump in the test set.

k. Repeat steps (b) through (j) for each pump in the test set.

7.3.3 Data Reduction and Analysis for the Deadhead Pressure Test

None required.

7.3.4 Data Reporting for the Deadhead Pressure Test

Record on the data reporting sheet in Table 10 the measured deadhead pressure (kPa), the associated pump serial number, the pump stall speed (rpm), and the pump current draw (A) for each test pump. This is to be done for the 5.0 VDC, 10 VDC, and 12.0 VDC applied voltages for each test pump. If the pressure relief valve was not activated at 12.0 VDC, record these values for each pump for the applied intermediate voltage above 12.0 VDC at which the pump relief valve was activated. This will be either 12.5 VDC, 13.0 VDC, 13.5 VDC, 14.0 VDC, 14.5 VDC, or 15.0 VDC. If the pressure relief valve is not activated even if 15.0 VDC is applied, then report the deadhead pressure, the stall speed, and the current draw for 15.0 VDC. Also clearly indicate on the data reporting sheet whether the pump pressure relief valve did or did not open.

7.4 Pump Delivered Flow Rate Test

7.4.1 Overview of the Pump Delivered Flow Rate Test

As one of the five key performance parameters, the delivered fuel flow rate (Q_d) of the in-tank, low-pressure fuel pump is perhaps the most important, and is a primary consideration when selecting a pump for an application. The delivered fuel flow rate is normally measured and specified at the rated delivery pressure and voltage for the particular pump design and application. The test is conducted on a standard fuel flow test bench (Figure 1) using the standard test fluid of Indolene unleaded gasoline at 21 °C ± 2 °C and an ambient pressure of 100 kPa ± 5 kPa. There are two types of basic flow tests, with the first being to determine the flow characteristics of the pump design for a range of delivered (back) pressures and applied DC voltages. The second type of flow test is a common one that is part of another pump test in this document. Many of the tests in this document—for example, the vibration test—require a series of pre-test and post-test measurements of key pump performance parameters in order to quantify the effect of the test on the pump performance. The pump flow at standard operating conditions is one of these key performance parameters.

7.4.2 Procedure for the Pump Delivered Flow Rate Test

a. A minimum set of five new pumps are to be tested. The pumps are to be selected from serial production. If this is a test to determine the flow characteristics of the pump design, then more pumps than five may be optionally tested if required. If a break-in preconditioning test has not been performed on the pumps to be tested, then perform a preconditioning on each of the test pumps by conducting a break-in procedure according to 6.5 step (a). If the delivered flow rate is being determined as part of the pre-test and post-test values of another test in this document, a set of five pumps from that particular test is to be tested.

b. If the delivered flow rate test is a test to determine the flow characteristics of the pump design, go to step (g).

c. For a delivered flow rate test that is a pre-test or post-test measurement of another test in this document, mount one or more new, preconditioned test pumps in a test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. Adjust the test stand pressure regulator to the rated fuel delivery (back) pressure for the pump being tested. Operate the pump(s) for 5 minutes at standard test conditions using the standard test fuel and an applied voltage of 12.0 VDC ± 0.1 VDC.

d. During the 5 minutes of operation, ensure that the fuel delivery pressure is stable at the rated value ±1.5%, the flowmeter indicates a fuel flow rate that is stable with fluctuations that do not exceed ±2%, and that the electrical current draw is stable within ±1.5%.

e. If the observed values of the pump rotor speed, pump current draw, fuel delivery pressure, and the delivered fuel flow rate are all stable within the specified limits during the observation period, note the values. Note the rotor speed (rpm), the current draw (A), the fuel delivery pressure (kPa), and the delivered fuel flow rate (L/h). If one or more parameters are not stable within the specified limits, note this as a deviation to be reported later, on the data reporting sheet.

f. If additional pumps in the set are to be tested, return to step (b) and mount the next pump. Then conduct steps (c), (d), and (e) for each remaining pump in the test set. If there are no more pumps to be tested, the test is complete.

g. For a test to determine the pump flow characteristics, mount the first pump in the test set of five or more new, preconditioned test pumps in a test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. For the first run, adjust the test stand pressure regulator to the conditions noted in Run 1 below, which are the rated fuel delivery pressure for the pump being tested and an applied standard DC voltage of 12.0 VDC ± 0.1 VDC. For subsequent runs, adjust the test stand pressure regulator and the applied voltage to the values indicated for that run. Operate the pump for 5 minutes for Run 1 at these conditions.

Table 1 - Flow rate test points

Run Number	Applied DC Voltage	Delivered (Back) Pressure
1	12.0	Rated delivery pressure
2	12.0	75% of rated delivery pressure
3	12.0	50% of rated delivery pressure
4	13.5	Rated delivery pressure
5	13.5	75% of rated delivery pressure
6	13.5	50% of rated delivery pressure
7	9.0	Rated delivery pressure
8	9.0	75% of rated delivery pressure
9	9.0	50% of rated delivery pressure

h. During the 5 minutes of operation, ensure that the fuel delivery pressure is stable at the rated value ±1.5%, the flowmeter indicates a fuel flow rate that is stable with fluctuations that do not exceed ±2% and that the electrical current draw is stable within ±1.5%.

i. If the observed values of the pump rotor speed, pump current draw, fuel delivery pressure, and the delivered fuel flow rate are all stable within the specified limits during the observation period, note the values. Note the rotor speed (rpm), the current draw (A), the fuel delivery pressure (kPa), and the delivered fuel flow rate in (L/h). After 5 minutes, if one or more parameters are not stable within the specified limits, note this as a deviation to be reported later on the data reporting sheet.

j. After completing a run, return to step (g) and increment the run number by one unit. Repeat steps (g) through (i) for the indicated applied voltage and back pressure that is listed in the new run number. After completing Run 9, the flow characteristics test for that particular pump is complete. If there are additional pumps in the test set to be tested, return to step (g), mount the next pump in the set into the test stand, and begin with the test conditions for Run 1. When Run 9 for the last pump in the test set has been completed, the entire flow characterization test is done.

7.4.3 Data Reduction and Analysis for Pump Delivered Flow Rate Test

None required.

7.4.4 Data Reporting for the Pump Delivered Flow Rate Test

The data reporting for this test may take two different forms. The first case is when the flow characteristics of a pump design are being evaluated, and the flow testing is not a part of any other test in this document. In that case, five (or more) pumps have been tested, and the measured data from this test are to be reported only on the data reporting sheet in Table 3. Extra copies of the 5C portion of the datasheet (one extra copy per pump) are to be used to accommodate the listing of all of the data for the five (or more) pumps that were tested for the stated range of applied voltages and back pressures. The serial number of each pump that was tested, along with the run number, and the corresponding measured value of the delivered fuel flow rate in liters per hour are to be reported on the data reporting sheet in Table 3 for each of the nine run numbers in step (g) of the test procedure. In addition, record the applied DC voltage and the pump delivery pressure (kPa), as well as the associated values of pump rotor speed (rpm) and the pump current draw (A) that were measured for that pump and that run. If one or more parameters were observed to be fluctuating during the observation period for any of the pumps that were tested, note this as a test deviation associated with that pump serial number on the data reporting sheet. For each pump tested, prepare a plot of the measured fuel flow in liters per hour versus the delivered (back) pressure for each applied DC voltage and attach the plot to the completed data recording sheet.

The second case is where a set of five pumps is being tested as part of another test in this document. In that situation—for example, the vibration test—five pumps have been tested to determine the delivered flow rates of each pump both before and after the vibration sequence has been applied. For that scenario for the five pumps, the values of the pump serial number, the delivered fuel flow rate, the delivery pressure, the current draw, and the pump rotor speed from this test will be recorded in the indicated spaces on the data reporting sheet in Table 3. Note that only the delivered fuel flow rate for each of the five pumps are to be reported on the data reporting sheet for the other test, such as on the vibration test datasheet.

8. FUEL PUMP LIMITATION TESTING

8.1 Introduction to Fuel Pump Limitation Testing

The fuel pump limitation testing of the in-tank, gasoline, low-pressure pump involves the conducting of individual tests that determine the performance of the pump when subjected to extreme conditions of operation. These tests are:

- Hot fuel handling.
- Cold magnet knockdown.
- Load dump transient.
- Electrical interference.
- Reverse flow leak.

8.2 Hot Fuel Handling Test

8.2.1 Overview of the Hot Fuel Handling Test

The hot fuel handling test involves submerging the pump completely in fuel contained in a tank wherein a low level of regulated pressure is maintained. While the pump is operating, the fuel temperature is increased in two-time increments at two specific rates over a 1 hour period from room temperature to an elevated temperature, specifically from 20 to 65 °C. The pump performance parameters are monitored and measured over this test period, with the emphasis being on determining the temperature at which a pump performance deterioration is first detected.

CAUTION: This test requires extreme caution. Both the test stand and room must be “explosion proof.” All electrical equipment should meet NEC Class I, Division I, Group D requirements or the regional equivalent.

8.2.2 Special Test Fluid for the Hot Fuel Handling Test

Bogey II is the special fluid to be used as the test fluid for the hot fuel handling test. The physical properties of Bogey II are in Appendix A, in Table A2. This special test fluid is specified because of safety concerns that are associated with the use of the standard test fuel of Indolene unleaded gasoline under such elevated temperature conditions. The hot fuel handling test should not be conducted unless Bogey II is utilized. Do not conduct this test using the standard test fluid.

8.2.3 Tank Fuel Volume

The volume of the stainless steel tank that is used for the hot fuel handling test is to be a minimum of 20 L and must be sufficient to completely cover the pump electrical connection throughout the test.

8.2.4 Requirements for Heating the Test Fuel

The heating of the test fuel requires extreme caution. See Figure 2 for a schematic of the hot fuel handling test stand that is required. The fuel should be heated indirectly by circulating the fuel in the tank through an external heat exchanger. This process can be done safely only by placing the test tank inside an explosion-proof thermal environmental chamber. Some experimentation will be necessary to determine the required flow rates through the heat exchanger, the inlet temperature of the heat exchanger, and the environmental chamber temperature that will result in the required heating rate.

8.2.5 Fuel Heating Rate

The fuel heating rate for the hot fuel handling test shall be as shown in Figure 4 and is:

- 1 °C/min from 20 to 50 °C (the first 30 minutes).
- 1/2 °C/min from 50 to 65 °C (the last 30 minutes).

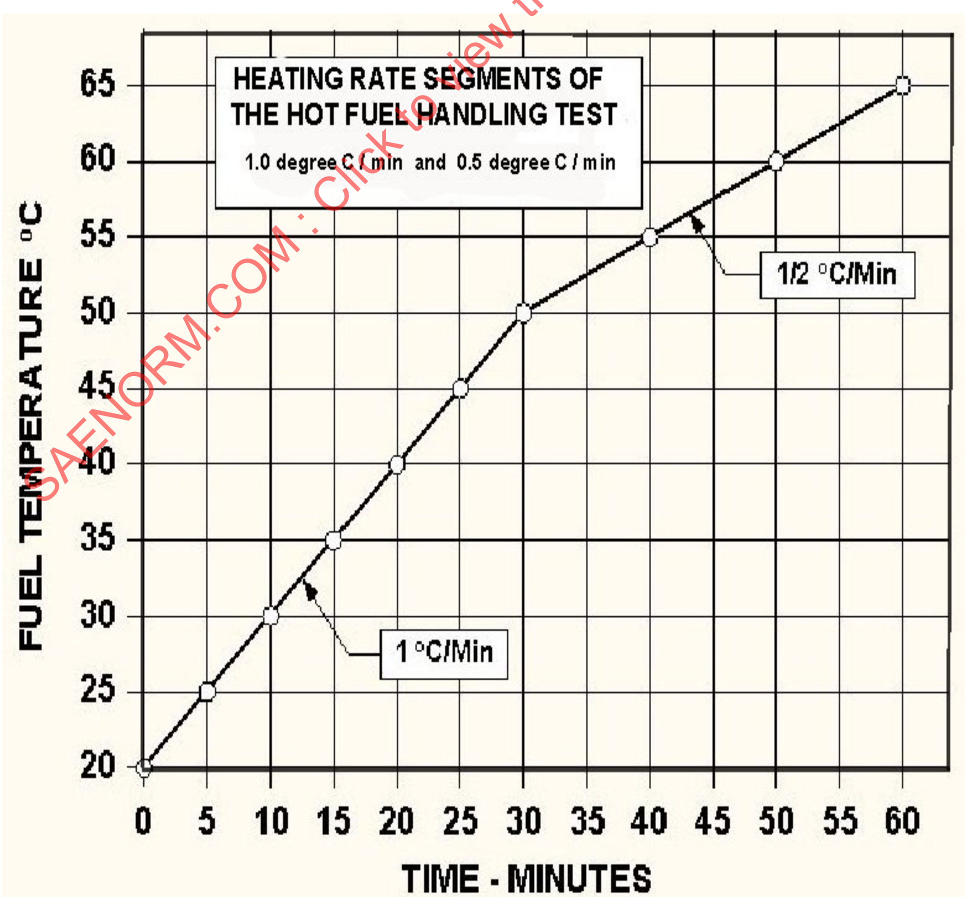

Figure 4 - Fuel heating rate for the hot fuel handling test

8.2.6 Pressure Settings

The tank vapor pressure regulator shall be set not to exceed 2.5 kPa. The pump pressure regulator shall be set at the system-rated pressure with the pump operating at rated flow at 12 VDC.

8.2.7 Operating Voltage

The applied pump voltage shall be 12 VDC ± 0.1 VDC during the test.

8.2.8 Fuel Delivery Line

The fuel delivery lines that convey the pressurized fuel from the pump outlet to a tank wall fitting and then on to the fuel flowmeter shall be a stainless steel flex line of 9.5 mm (3/8 inch) internal diameter.

8.2.9 Procedure for the Hot Fuel Handling Test

a. A minimum of five new pumps are to be tested, with one pump tested at a time. More pumps may be optionally tested if desired. The pumps are to be selected from serial production. Precondition each of the test pumps by conducting a break-in procedure according to 6.5 step (a).

b. In preparation for the initial pre-test performance parameter measurements, mount a new, preconditioned test pump in a standard test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. Operate the pump for 5 minutes at standard test conditions using the standard test fuel and an applied input voltage of 12.0 VDC.

c. For each new, preconditioned pump in the test set, measure the four performance parameters of pump speed, current draw, electrical resistance, and the delivered fluid flow rate at the rated delivery pressure at an applied voltage setting of 12.0 VDC, according to the appropriate test procedures for those variables. These procedures are detailed in 7.2, 7.3, and 7.4. The parameter values that are obtained for the standard test fluid temperature of 20 °C at the initiation of the test are to be denoted as the pre-test standard test fluid values, and are to be associated with the serial number of that particular pump.

d. Remove the pump from the standard test stand. If additional pumps remain in the test set, return to step (b) and conduct steps (b) and (c) for the next pump in the set. Test all pumps in the test set for the pre-test performance values before performing any hot fuel handling testing.

e. When the pre-test standard test fluid values have been measured for all pumps in the test set, move the pump set to the hot fuel handling test bench.

f. Mount a test pump in the hot fuel handling test bench by attaching it to a holding fixture that suspends the inlet filter at least 25 mm from the tank bottom. Fill the test tank to the desired level with fresh Bogey II test fluid that has been stored at approximately 15 °C. While maintaining a test fluid temperature below 20 °C, flow the pump on the Bogey II test fluid for 5 minutes using an applied voltage of 12 VDC and at the rated operating pressure of the pump.

g. For each pump in the test set, continuously run the pump, and continuously monitor the four performance parameters of pump speed, current draw, electrical resistance, and the delivered fluid flow rate. This is to be done using Bogey II as the test fluid, using an applied input voltage setting of 12.0 VDC and operating at the rated delivery pressure. Adjust the test fluid temperature to a stabilized value of 20 °C and measure the performance parameters. The four performance parameter values that are obtained for a test fluid temperature of 20 °C at the initiation of the test are to be denoted as the pre-test Bogey II values, and are to be associated with the serial number of that particular pump. Measure these values prior to any application of a timed heating of the test fluid.

h. Start the time clock and initiate the heating of the test fluid. The Bogey II test fluid shall be heated to provide the time-varying values of fluid temperature that are illustrated in Figure 4. Operate the pump continuously at 12.0 VDC and at the rated delivery pressure through the temperature range from 20 to 65 °C at the timings indicated. A manual pressure regulator can be adjusted as the fluid temperature increases in order to maintain a constant rated delivery pressure. If the limit of pressure regulation is reached at which the desired outlet pressure can no longer be maintained due to cavitation or vapor lock, note the fluid temperature at which this first occurs. Record the pump voltage, outlet pressure, delivered flow rate, current draw, pump speed, and fuel temperature at a minimum of one sample every 5 seconds. A more frequent data rate may be optionally utilized as required.

i. After 1 hour, and after attaining the maximum test fluid temperature of 65 °C, cease the heating of the test fluid and end the test for that pump. Quickly and safely remove the test pump from the flow bench and allow it to cool to room temperature.

j. Allow the fluid temperature of the hot fuel handling test bench to return to a temperature of 20 °C. Remove and dispose of the Bogey II test fluid after each pump is tested. If there are additional pumps remaining in the test set, repeat steps (f) through (i) for the next pump. Use a new volume of pre-cooled Bogey II for each pump. Once the final pump in the test set has been subjected to the hot fuel handling test cycle, allow all of the test pumps to cool to room temperature.

k. For ascertaining whether any permanent effects of high temperature operation on the pump performance parameters occurred, steps (k) through (m) are to be conducted. Return all of the test pumps to the standard test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. Mount a pump and operate it for 5 minutes at standard test conditions using the standard test fuel of Indolene unleaded and an applied input voltage of 12.0 VDC.

l. Measure the four performance parameters of pump speed, current draw, electrical resistance, and the delivered fluid flow rate at the rated delivery pressure at an applied voltage setting of 12.0 VDC, according to the appropriate test procedures for those variables. These procedures are detailed in 7.2, 7.3, and 7.4. The parameter values that are obtained for the standard test fluid temperature of 20 °C at the end of the test are to be denoted as the post-test standard test fluid values, and are to be associated with the serial number of that particular pump. The post-test standard test fluid values may be compared to the pre-test standard test fluid values to quantify any performance differences that occurred due to operation at a significantly elevated level of fuel temperature.

m. Remove the pump from the standard test stand. If additional pumps remain in the test set, return to step (k) and conduct steps (k) and (l) for the next pump in the set. When the final pump in the set has been tested for the post-test standard test fluid values, all testing associated with hot fuel handling has been completed.

8.2.10 Data Reduction and Analysis for the Hot Fuel Handling Test

For the values of the four key performance parameters that were measured during the heating portion of the hot fuel handling test, plot each one of the values and the corresponding test fluid temperature versus the test time in minutes on the x-axis. Also include the target fluid temperature from Figure 4 on the same plot. The plots should be reviewed for consistency in performance parameters among the pumps at all fuel temperatures. Significant decreases or erratic values in delivered flow rate, current draw, or outlet pressure, as well as increases or erratic values in pump speed are indications that cavitation and vapor lock conditions are being created within the fuel pump.

From the plots of the measured variations in the four performance parameters, note the minimum values of outlet pressure, flow rate, and current draw, as well as the maximum value of pump speed. Also note the values of the test fluid temperature at which each minimum (or maximum for pump speed) occurred, as well as the lowest temperature value for which the rated outlet pressure could no longer be maintained.

To quantify the degree to which any permanent performance effects of operation at elevated temperatures occurred, compute the changes in each of the performance variables from pre-test Indolene to post-test Indolene.

To quantify the degree to which the performance parameters are altered by operating on Bogey II fluid instead of on the standard test fluid of Indolene, compute the changes in each of the performance variables from pre-test standard test fluid values (Indolene) to the pre-test Bogey II values

8.2.11 Data Reporting for the Hot Fuel Handling Test

Record on the data reporting sheet in Table 4 for each test pump the pre-test performance parameter measurements for Indolene, the pre-test performance parameter measurements for Bogey II and the minimum values of each performance parameter (maximum for pump speed) that are determined from the plots indicated in 8.2.10. This will quantify the degree of change that occurs due to using Bogey II instead of Indolene unleaded gasoline. These measured values are to be provided on the data reporting sheet in Table 4 for each pump. For each pump for which there was a Bogey II temperature reached at which the rated delivery pressure could not be maintained, report that fluid temperature in parentheses immediately after the serial number for that pump in Part 5 of the data reporting sheet in Table 4.

To quantify the extent to which any permanent effects of operation at elevated temperatures occurred, record the values of the performance parameters for pre-test standard test fluid (Indolene), post-test standard test fluid (Indolene), and the changes from pre-test Indolene to post-test Indolene. To quantify the extent to which pump operation is altered by using Bogey II instead of Indolene, record the percentage changes from pre-test Indolene to pre-test Bogey II. All changes are to be reported as percentages, except for amperes. These are to be recorded on the data reporting sheet in Table 4.

8.3 Cold Magnet Knockdown Test

8.3.1 Overview of the Cold Magnet Knockdown Test

This test is utilized to verify the robustness of the permanent magnets in the pump motor regarding the ability to withstand worst-case, combined conditions of temperature and applied voltage. The pump is immersed for 2 hours in Indolene unleaded gasoline at a temperature of -35 °C, then five consecutive applications of 24 VDC are applied to the electrical terminals. The effects of this application on subsequent pump operation are then ascertained.

8.3.2 Procedure for the Cold Magnet Knockdown Test

a. A minimum of five new pumps are to be tested, with one pump tested at a time for the key performance parameters, but all pumps in the set tested as a group for the cold magnet knockdown. More pumps than five may be optionally tested for the cold magnet knockdown if desired, but it is convenient to test them in groups of five. The pumps are to be selected from serial production. Precondition each of the test pumps by conducting a break-in procedure according to 6.5 step (a).

b. For each new, preconditioned test pump, mount the pump in a standard test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. Operate the pump for 5 minutes at standard test conditions using the standard test fuel.

c. Measure the five key performance parameters of the delivered flow rate at rated pressure, the pump speed, the normal current draw, the electrical resistance, and the deadhead pressure at standard test conditions, according to the appropriate test procedures for those variables. These are the tests that are detailed in 7.2, 7.3, and 7.4. The parameter values that are obtained are to be denoted as the pre-test values. Associate the specific pre-test measurements with the serial number of the pump.

d. If there are additional pumps in the pump test set, repeat steps (b) and (c) for each pump.

e. If all pumps in the test set have had their pre-test values measured, next immerse all of the test pumps in the test set for 2 hours in Indolene unleaded gasoline that has a temperature of -35 °C.

f. Leaving the pumps immersed and utilizing a regulated DC power supply set to 24.0 VDC, energize all pumps five times for 5.0 seconds with a 5.0 second off time (dwell) between voltage applications. Note that this applied voltage is not 12 VDC.

g. Following the five voltage applications, remove all of the pumps in the test set from immersion and allow them to return to room temperature. Move the entire test set to the standard flow test bench.

h. Repeat steps (b) and (c) for each pump in the test set regarding the measurement of the five key performance parameters, with the exception that the five key performance values that are measured are now to be denoted as post-test values. Ensure that each set of pre-test and post-test values are associated with the correct pump serial number.

8.3.3 Data Reduction and Analysis for the Cold Magnet Knockdown Test

Compute the pre-test to post-test change for each test pump for each of the five performance parameters. The changes of flow at rated pressure, the pump speed, the normal current draw, and deadhead pressure are to be computed as a percentage.

8.3.4 Data Reporting for the Cold Magnet Knockdown Test

Record on Part 5 of the data reporting sheet in Table 5 for the cold magnet knockdown test the five key performance parameters of the flow rate at rated pressure (L/h), the pump speed (rpm), the normal current draw (A), the electrical resistance (Ω), and the deadhead pressure (kPa) that were measured both prior to and after the five applications of 24.0 VDC. Also record the computed change in each of the five performance parameters. The changes of flow, pump speed, and deadhead pressure are to be reported as a percentage. Do this for each pump that was tested.

8.4 Load Dump Transient Test

This is a test to determine the degree to which the gasoline, in-tank electric fuel pump is affected by electrical transients on the power leads. The reference document is SAE J1113/11. The specific portion of the document is Section 5. The load dump refers to the electrical response that is associated with the sudden disconnection of the powered load or a voltage pulse application to an electrical device—in this case, an electrical in-tank pump. The details of the test list are fully described in SAE J1113/11 and consist of numerous options for the number and severity of applied voltage waveforms, and for the spacing and frequency of voltage supply disconnection of an inductive load. These tests are used to ascertain the level of immunity of the device to electrical transients, which may be a single or multiple injection of voltage pulses or may be a single or periodic disconnection and restoration of the electrical supply. Figures 2 through 5 in SAE J1113/11 illustrate numerous test waveforms and periodicities that may be optionally utilized for the electrical event, and Tables 2 through 6 provide optional test parameter values for 12 V automotive components.

The load dump transient test shall be run per Figures 2 and 3 in SAE J1113/11. Additional transient electrical event (or events) may optionally be run when agreed to jointly by the pump manufacturer and the end user, and will normally be one of the events depicted in the noted figures and tables. The test procedure in this document calls for a pre-test measurement of the five key pump performance parameters, followed by the application of the selected (or agreed-upon) electrical transient or set of transients from SAE J1113/11, and then a post-test remeasurement of the same five performance parameters. This will establish the degree to which the load dump transient influenced the pump performance.

8.4.1 Procedure for the Load Dump Transient Test

a. A minimum of five new pumps are to be tested for each load transient test, with one pump tested at a time. More pumps may be optionally tested if desired. The pumps are to be selected from serial production. Precondition each of the test pumps by conducting a break-in procedure according to 6.5 step (a).

b. For each new, preconditioned test pump, measure the five key performance parameters of pump speed, current draw, electrical resistance, deadhead pressure, and the delivered fluid flow rate at the rated delivery pressure at an input voltage setting of 12 VDC, according to the appropriate test procedures for those variables. These are the tests that are detailed in 7.2, 7.3, and 7.4. The parameter values that are obtained are to be denoted as the pre-test values, and are to be associated with the serial number of that particular pump. Measure these values prior to any load dump transient testing.

c. Conduct the selected (or agreed-upon) electrical transient or set of transients from the listing of available standard pulse applications and supply disconnections that are listed in Figures 2 through 5 and Tables 2 through 6 in SAE J1113/11. The test equipment required is listed in detail in that document.

d. For each pump that is tested, again measure the five key performance parameters of pump speed, current draw, electrical resistance, deadhead pressure and the delivered fluid flow rate at the rated delivery pressure at an input voltage setting of 12 VDC, according to the appropriate test procedures for those variables. The parameter values that are obtained are to be denoted as the post-test values, and are to be associated with the serial number of that particular pump.

8.4.2 Data Reduction and Analysis for the Load Dump Transient Test

Compute the pre-test to post-test change for each test pump for each of the five performance parameters. The changes of flow at rated pressure, the pump speed, the normal current draw, and deadhead pressure are to be computed as a percentage.

8.4.3 Data Reporting for the Load Dump Transient Test

Record on Part 5 of the data reporting sheet in Table 5 the measured value and the computed change from the pre-test to the post-test condition for each of the five key performance parameters. This is to be done for each pump that was tested. The changes in the flow rate at standard pressure, the pump speed and the deadhead pressure are also to be reported as a percentage.

8.5 Electrical Interference Test

8.5.1 Introduction to the Electrical Interference Test

The electrical interference testing of an in-tank, low-pressure gasoline pump has the goal of quantifying the levels of electromagnetic interference (EMI) and the radio frequency interference (RFI) that may be associated with the operation of that pump. These values are metrics that may optionally be considered regarding the possible level of interference with other components of the vehicle electrical system that are the result of operating the pump. Examples of such equipment would be the audio or GPS systems. A vehicle operating system may continuously modulate the electrical current that is delivered to the in-tank pump, and this current variation may generate electrical disturbances that could negatively affect the normal operation of other components. The specifics of the two tests are not detailed in this document, but will rely on proven third-party standards and recommended practices that are in use throughout the automotive industry. Specifically, this will be ISO 7637-2 (2011). This is a bench test that utilizes pulsed signals to evaluate the transient electrical emissions of a fuel pump.

8.5.2 Procedure for Electrical Interference Testing

The test procedure and the equipment requirements are provided in the referenced ISO Standard document

8.5.3 Data Reduction and Analysis for Electrical Interference Testing

The required data reduction procedures are provided in the referenced ISO Standard document.

8.5.4 Data Reporting for Electrical Interference Testing

The measured parameters that are to be reported for electrical interference testing are provided in the referenced ISO Standard. These may be reported on the data reporting sheet in Table 6.

8.6 Reverse Flow Leak Test

8.6.1 Introduction to the Reverse Flow Leak Test

The reverse flow leak rate of an in-tank electric gasoline pump represents a measure of the rate at which pressurized fuel downstream of the pump outlet (in the fuel line and in the rail) bleeds back through the pump and returns to the fuel tank. This occurs when the in-tank fuel pump is not operating during an engine-off time period that follows an engine-on period. The fuel rail pressure available to the fuel injectors for a subsequent engine start will decrease more rapidly as the reverse flow leak rate is increased.

8.6.2 Test Parameters for the Reverse Flow Leak Test

- Test pressure: 520 kPa ± 10 kPa.
- Test temperature: 21 °C ± 2 °C.
- Test fluid: Indolene unleaded gasoline.

8.6.3 Procedure for the Reverse Flow Leak Test

a. Five new pumps from serial production are to be tested, with one pump tested at a time. More pumps may be optionally tested if desired. The pumps are to be selected from serial production. Precondition each of the test pumps by conducting a break-in procedure according to 6.5 step (a). After the break in procedure, each test pump is to be installed into the reverse flow leak test fixture that is shown schematically in Figure 3.

b. The pump outlet is to have the original outlet fitting installed, along with the original fuel line that leads to the measuring burette.

c. Referring to the test fixture shown in Figure 3, adjust the nitrogen supply to maintain the test pressure of 520 kPa while keeping the test pressure valve shut.

d. Next, open the bleed valve while keeping the test pressure valve and drain valve closed.

e. Open the refilling valve to refill the measuring tube with Indolene unleaded gasoline to an indicator line near the top of the tube so that the level of the test fluid can be easily viewed. The measuring tube shall have measuring lines indicated in milliliters (mL).

f. Close both the refilling valve and the bleed valve.

g. Reset the level index needle to the starting level of the Indolene unleaded gasoline in the measuring tube.

h. Open the test pressure valve to apply the test pressure to the surface of the test fluid in the measuring tube.

i. After 1 hour, note the decreased level of the test fluid in the measuring tube.

j. Shut the test pressure valve and slowly open the bleed valve to release the remaining line nitrogen pressure.

8.6.4 Data Reduction and Analysis for the Reverse Flow Leak Test

Convert the observed leakage volume of test fluid to an hourly rate (mL/h).

8.6.5 Data Reporting for the Reverse Flow Leak Test

Report the converted hourly leakage rate of the test fluid on the data reporting sheet in Table 10.

9. FUEL PUMP INTEGRITY TESTING

The classification of fuel pump integrity testing includes four individual tests that are designed to provide key information on the integrity and functional durability aspects of the pump. These tests are:

- Vibration.
- Temperature cycling.
- Internal fluid compatibility.
- Operational durability.

9.1 Vibration

9.1.1 Introduction to the Vibration Test

The goal of the vibration test is to determine the effect of sustained vibration on the key pump performance parameters. The pump is to be subjected to controlled g-forces on each of three axes while mounted on a vibration fixture. A typical representation of such a test fixture is depicted in Figure 5. Representative performance parameters are measured both before and after the vibration test to ascertain the level of changes that result from the test.

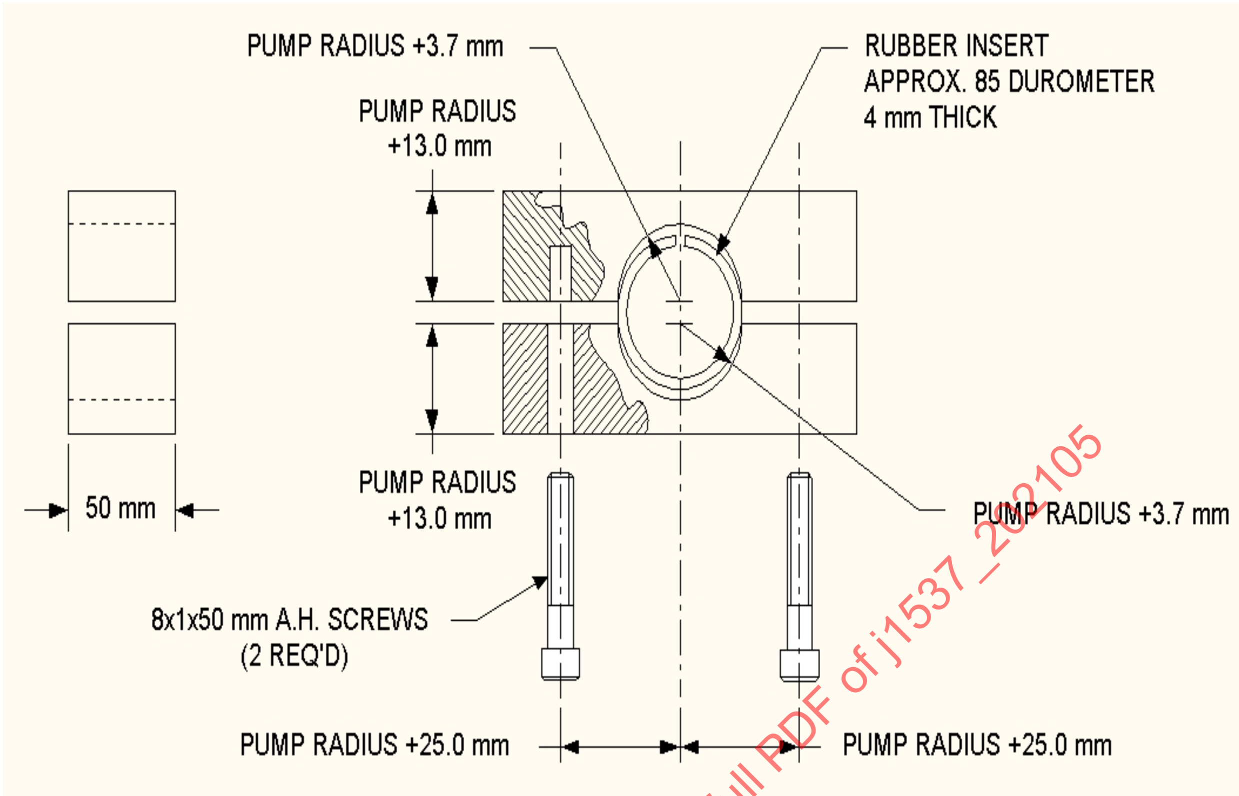

Figure 5 - Representative pump vibration test fixture

9.1.2 Procedure for Vibration Testing

a. Five new identical pumps from serial production are to be tested. More pumps may be optionally tested if desired. They may be tested individually or in a group. Each test pump is to be preconditioned by conducting a break-in procedure according to 6.5 step (a).

b. Pre-test measurements shall be made on all test pumps for the values of the five key performance parameters. These parameters are the flow rate at rated pressure, pump current draw, pump speed, pump electrical resistance, and deadhead pressure. The tests for these parameters are detailed in 7.2, 7.3, and 7.4.

c. The test pump(s) are to be mounted on the vibration table with the desired first axis in the proper orientation. The pump(s) are to be completely dry, and with no voltage applied (non-energized).

d. The vibration test cycle is to then be conducted as represented schematically in Figure 6. A target peak-to-peak displacement of 1.5 mm shall be used for the frequency range from 10 to 38.6 Hz, and a maximum acceleration of 4.5 g should be maintained from 38.6 to 55.0 Hz. The forcing function shall be a sine wave with the frequency of vibration varying with time as illustrated in the schematic.

e. After applying the vibration for 1 hour in the first axis, stop the vibration and shift the orientation of the pump(s) to vibrate along the second axis.

f. Apply the vibration cycle per Figure 6 for 1 hour along the second axis, which is to be perpendicular to the first axis.

g. After applying the vibration for 1 hour in the second axis, stop the vibration and shift the orientation of the pump(s) to the third and final axis, which is to be mutually perpendicular to both the first and second axes.

h. Apply the vibration cycle per Figure 6 for 1 hour along the third axis of the pump(s).

i. Following the completion of the 3 hours of applying the vibration cycle, stop the vibration and remove the pump(s).

j. Inspect each pump and note any visible damage. Convey all of the pumps to a standard flow test stand.

k. Conduct post-test measurements of the same five key performance parameters that are listed in step (b).

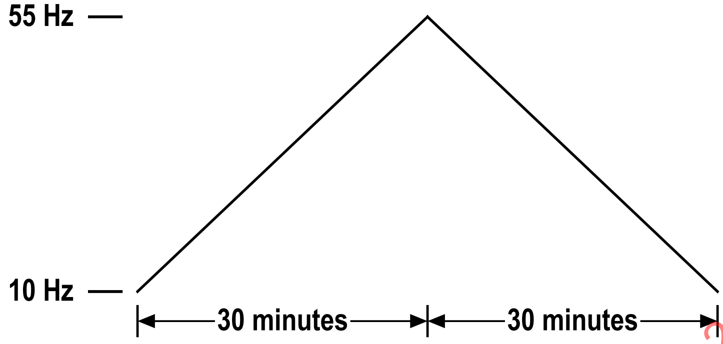

Figure 6 - Test cycle for the pump vibration forcing frequency

9.1.3 Data Reduction and Analysis for the Vibration Test

For the values of the five key performance parameters that were measured both before and after the vibration test, compute the change in each parameter. For the flow rate at standard pressure, the pump speed and the deadhead pressure, compute the observed change as a percentage. This is to be done for each pump that was tested. Also, inspect each test pump for any visible signs of damage.

9.1.4 Data reporting for the Vibration Test

Record on the data reporting sheet in Table 7 the measured value and the computed change from the pre-test to the post-test condition in each of the five key performance parameters. The changes in the flow rate at standard pressure, the pump speed, and the deadhead pressure are to be reported as a percentage. Any visible signs of damage that are evident from the inspection should be described in the comments section of the data-reporting sheet.

9.2 Temperature Cycling Test

9.2.1 Introduction to the Temperature Cycle Test

This test is employed to ascertain the effects of fuel temperature extremes on pump performance. The pump is to be subjected to repeated cycles of heating and cooling from +75 to -30 °C over a 120 hour time period. The effect of these temperature cycles on the performance of the pump is then ascertained by means of measuring the five key performance parameters both before and after all of those cycles are completed.

9.2.2 Procedure for the Temperature Cycle Test

a. A minimum of five new pumps are to be tested. More pumps may optionally be tested if desired. They are normally tested simultaneously as a test set. The pumps are to be selected from serial production. Precondition each of the new test pumps by conducting a break-in procedure according to 6.5 step (a).

b. For each new, preconditioned test pump, mount the pump in a standard test stand that is capable of operation using Indolene unleaded gasoline as the test fluid. Operate the pump for 5 minutes at standard test conditions using the standard test fuel and an applied input voltage of 12.0 VDC.

c. Measure the five key performance parameters of the delivered flow rate at rated pressure, the pump speed, the normal current draw, the electrical resistance, and the deadhead pressure at standard test conditions, according to the appropriate test procedures for those variables. These are the tests that are detailed in 7.2, 7.3, and 7.4. The parameter values that are obtained are to be denoted as the pre-test values. Associate the specific pre-test measurements with the serial number of the pump.

d. The set of pumps is to be placed or hung in a containment area where the air surrounding the pumps can be heated and cooled automatically according to the rates and temperature limits depicted in Figure 7. The test pumps are to be dry, with no test fluid inside. Also, the pumps are not to have any voltage applied to the pump terminals (non-energized) during the test.

e. Twenty temperature cycles are to then be conducted as shown in Figure 7. For each cycle, the pump shall be alternately heated and cooled in an air environment having a temperature that is varied from +75 to -30 °C and back over a 6 hour period.

f. Apply each test cycle for 6 hours, as per Figure 7, for a total test duration of 120 hours.

h. Following the completion of the 20 temperature cycles, each of the test pumps is to be cooled to room temperature and inspected for any signs of damage. Then they are to be retested on a standard flow test stand as was done in step (b) to determine the post-test values of the five key performance parameters.

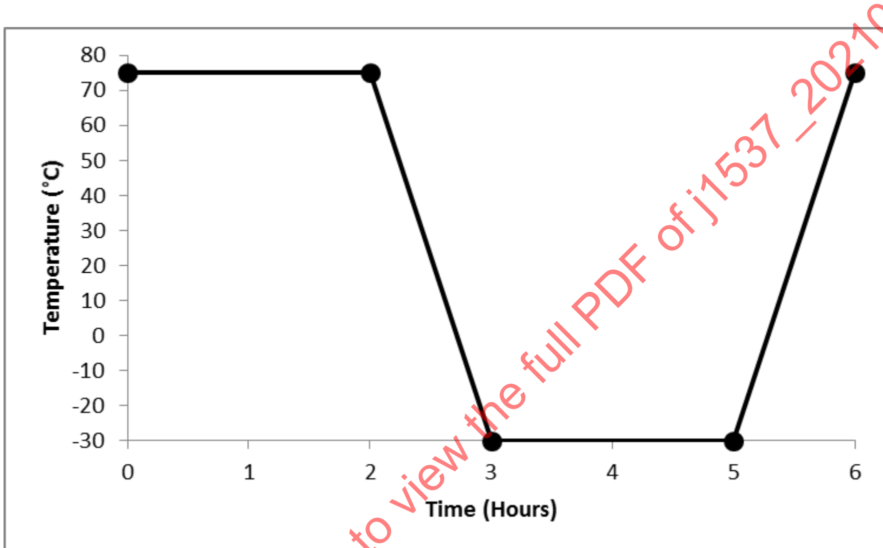

Figure 7 - Temperature cycle test schedule

9.2.3 Analysis and Data Reduction for Temperature Cycling

For the values of the five key parameters, calculate the changes from pre-test to post-test. The parameters of delivered flow rate, deadhead pressure, and pump speed are to be reported as a percentage change. Inspect each test pump for any visible signs of damage.

9.2.4 Data Reporting for Temperature Cycling

Record on the data reporting sheet in Table 4 the measured value and the computed change from the pre-test to the post-test condition for each of the five key performance parameters. This is to be done for each pump that was tested. The changes in the delivered flow rate at standard pressure, the pump speed, and the deadhead pressure are to be reported as a percentage change. Any visible signs of damage that are evident from the inspection should be described in the comments section of the data-reporting sheet.

9.3 Internal Fluid Compatibility Test

This test is used to determine the compatibility of internal fuel pump components with fluids similar to those that may possibly be utilized in the application fuel system during the operating lifetime of the vehicle.

9.3.1 Immersion Test Fluids

a. ASTM Reference Fuel C (50% iso-octane 2-2-4 tri-methylpentane, 50% toluene) per ASTM D4814.

b. Water/Reference C Solution (corrosive fuel). Mix by volume, 98% ASTM Reference Fuel C and 2% corrosive water. Corrosive water is a solution formed by dissolving 165 mg of sodium chloride in 1 L of distilled water (per SAE J1681). The water may be heated to 40 °C to aid the mixing.

c. ASTM Reference Fuel C and 15% methanol. Shall be 15% by volume reagent-grade methanol added to ASTM Reference Fuel C. For this fuel, the reference publication SAE J1747 should be reviewed for meaningful time-saving suggestions on testing with gasoline-methanol mixtures.

d. ASTM Reference Fuel C and 10% ethanol. Shall be 10% by volume reagent-grade ethanol added to ASTM Reference Fuel C. The ethanol must meet the requirements of ASTM D4806.

e. ASTM Reference Fuel C and 85% ethanol (E85). Shall be 85% by volume reagent-grade ethanol added to ASTM Reference Fuel C. The ethanol must meet the requirements of ASTM D4806.

f. Oxidized gasoline (sour gas). Shall be mixed by the following procedure to achieve a peroxide number of 180 millimole/L. Steps in the preparation of the sour gas oxidized gasoline test fluid:

1. First, prepare the stock fuel—ASTM Reference Fuel B (70% iso-octane 2-2-4 tri-methyl pentane, 30% toluene)—per ASTM D4814.

2. Second, prepare the peroxide stock solution: dilute 335 mL of 90% by weight t-butyl hydroperoxide with 665 mL of n-Heptane.

3. Third, prepare the copper ion stock solution. Note: Failure to follow proper procedures can result in a fire. Refer to OSHA safety data sheets for these chemicals. Due to the hazardous nature of these chemicals, the solution must be prepared sequentially in the following three steps:

   i. Add 10 mL of 12% copper ion concentrate solution to 990 mL of stock fuel.

   ii. Add 100 mL of the peroxide solution to 1040 mL of stock fuel.

   iii. Dilute 10 mL of the solution obtained in step 2 with 990 mL of stock fuel.

4. Fourth, prepare the sour gas oxidized gasoline test solution: dilute 60 mL of peroxide stock solution with 10 mL of copper ion stock solution and 93 mL of stock fuel.

9.3.2 Test Procedure for Internal Fluid Compatibility Testing

a. Five new pumps are to be tested for each fuel solution listed above. More than five pumps may be optionally tested if desired. The set of pumps shall be tested as a group. A set of new pumps shall be used for each fuel blend that is tested. Pre-condition each of the new test pumps by conducting a break-in procedure according to 6.5 step (a). For each pump being tested, measure the pre-test values of the five key performance parameters of deadhead pressure, the delivered flow at rated pressure, the electrical resistance, and the pump current draw and pump speed at the rated delivery pressure and voltage. These pre-immersion measurements should be obtained using the standard test fluid of Indolene unleaded.

b. Next, drain each test pump of the standard test fluid and place it in the container tank containing the particular internal fluid compatibility test fluid that is being utilized. Use 1/2 to 1 L of fuel solution per pump in the container, but ensure that the quantity of fuel solution is adequate to completely submerge the pump(s) being tested.

c. Each pump that is being tested is to be initially operated at the standard voltage of 12 VDC for 5 seconds to completely purge any entrained air, and to ensure that it is filled with the immersion fluid. The solution container is then to be sealed air-tight and maintained undisturbed for 720 hours (30 days) at 21 °C ± 4 °C.

d. Following the immersion test, each pump is to be checked to determine if it will start pumping unassisted in the test fluid with 12 VDC applied to the terminals. After 720 hours of immersion, remove the sealing lid of the solution container and attempt to start each pump within a maximum of 20 seconds by applying 12 VDC to the electrical terminals while the pump is still submerged in the test fluid. Each test pump that does not start unassisted should be removed from the immersion tank and set aside for later inspection.

e. For each test pump that starts unassisted, remove it from the immersion bath and purge it using the standard test fluid of Indolene unleaded. Operate each pump for 15 minutes using the standard test fluid, then measure the five standard performance parameters of deadhead pressure, the delivered flow at rated pressure, the electrical resistance, and the pump current draw and pump speed at the rated delivery pressure and voltage. Do not make measurements on those pumps that did not start unassisted.

f. Repeat steps (a) through (e) for the next internal fluid compatibility test fuel, using a set of five new pumps.

9.3.3 Data Reduction and Analysis for Internal Fluid Compatibility Testing

For each immersion fluid, all of the pumps tested are to be visually inspected for damage or deformity. Any pump that fails to start unassisted after immersion should also have an inspection to determine the reason for the failure. For those pumps that did start unassisted, and for which pre-immersion and post-immersion performance data were obtained, the changes in each of the five performance parameters shall be computed. The changes for the performance parameters of flow at rated pressure, deadhead pressure and pump speed should be computed as a percentage change

9.3.4 Data Reporting for Internal Fluid Compatibility Testing

On the data reporting sheet in Table 8, record the pre-immersion and post-immersion values for the pump flow at rated pressure, the deadhead pressure, the electrical resistance, and the pump current draw and pump speed at the rated delivery pressure and voltage. Record the computed change in each of the five parameters, with the changes for flow at rated pressure, deadhead pressure, and pump speed recorded as a percentage change.

Record the visual observations of each tested pump, providing a description of any observed damage or deformity. For any tested pump that does not start unassisted after immersion, indicate the results of the inspection regarding the reason for non-starting. Record the serial numbers of all of the pumps that were tested, indicating which pumps failed to start unassisted.

9.3.5 Optional Test Procedure Modification using an Elevated Temperature

An additional optional procedure for internal fluid compatibility testing is to test for immersion in one or more of the listed fuel solutions, or for an additional non-listed fuel solution, at an elevated temperature that is agreed upon by both the manufacturer and the user. This may be combined with a reduced time of immersion that is also agreed upon. If this test modification is used, it must be noted as a test deviation on the data reporting sheet.

9.4 Operational Durability Test

The basic operational durability or life cycle test involves running fuel pumps for 3000 hours (or optionally longer) in test fuel on a cycle which includes start-and-stop operation. Four different test fuels are specified, including two common fuels and two that are of a corrosive nature. The common fuels are run for 3000 hours, while each of the two corrosive fuels are run for 1800 hours. A new set of pumps shall be tested for each fuel type.

9.4.1 Requirements for the Operational Durability Test

a. Tank size: The tank for the test fuel shall be stainless steel, and have a volume of not less than 54 L. For a pump test set of more than six pumps, a tank volume of at least 9 L of test fuel for each pump running in the tank is required.

b. Fuel change interval: The fuel in the tank shall be changed every 168 hours ± 8 hours.

c. Fuel level: The level of the test fuel shall be such that all of the test pumps are fully immersed, including the pump electrical terminals.

d. Pump mounting: The pump shall be mounted in the tank in the same orientation as it would be in the intended application. If the pump orientation is unspecified, the pump should be mounted with the centerline of the pump in the vertical direction.

e. Filters (inlet and outlet): The pump shall be fitted with an inlet filter that meets the particle pass and pressure drop specifications of the pump manufacturer. Each pump outlet shall also be fed into an automotive in-line filter as is used in gasoline fuel injector applications (typically 10 to 20 μm).

9.4.2 Fuels for the Operational Durability Test

The operational durability test shall be performed with a minimum of the following four test fuels:

a. E10 ethanol blend: Unleaded gasoline with 10% volume ethanol (gasoline grade).

b. E85 ethanol blend: 85% ethanol, 15% unleaded gasoline.

c. Low lubricity gasoline: 99.8% n-Heptane, 0.2% corrosive water.

d. Corrosive E22: 77% unleaded gasoline, 22% ethanol, 1% corrosive water.

NOTE: Corrosive water is a solution formed by dissolving 165 mg of sodium chloride in 1 L of distilled water, as per SAE J1681. The water may be heated to 40 °C to aid in the mixing process.

The operational durability test for in-tank pumps may also be optionally conducted using other test fluids in addition to the minimum four listed above. If such additional optional fluids are used and tests are performed, the data outlined in the test procedure and the data analysis should be taken and reported. In addition, each additional test fluid should be reported on the data reporting sheet and be fully defined in an attachment to that sheet.

9.4.3 Procedure for the Operational Durability Test

a. A minimum set of five new, identical pumps from serial production shall be used for this test. They should be mounted as specified in 9.4.1. More than five pumps may optionally be tested if desired. A new set of pumps shall be used for each test fluid. Each test pump in the set shall be preconditioned as noted in 6.5 step (a).

b. Electrical input: The pumps shall be operated at 13.5 VDC ± 0.5 VDC, as measured at the pump terminals. A provision for an automated, periodic start and stop shall be provided at the test stand.

c. Pump output pressure: The pumps are to be operated at an outlet pressure of P_{NORM} ±10 kPa. If P_{NORM} for the intended pump application is not specified, the test is to be performed with a pump output pressure of 520 kPa ± 10 kPa. Either 520 kPa or P_{NORM} will be considered as the rated delivery pressure as referred to in subsequent steps.

d. The five key pump performance parameters of deadhead pressure, the delivered flow at the rated pressure, the pump electrical resistance, the pump current draw and the pump speed at the rated delivery pressure and voltage shall be measured for each test pump using Indolene unleaded gasoline prior to the initiation of any operational durability testing.

e. Each set of test pumps shall be run for 3000 hours for test fluids (A) and (B) at the nominal fuel temperature of +33 °C ± 3 °C. During the test, each of the test pumps shall be turned off every 20 minutes for 6 seconds ± 2 seconds. If tests are being conducted using either fuels (C) or (D), each set of test pumps shall be run for 1800 hours at the nominal fuel temperature of +33 °C ± 3 °C. During the test, each of the test pumps shall be turned off every 20 minutes for 6 seconds ± 2 seconds. A maximum test duration of more than 3000 hours for test fluids (A) and (B) may optionally be used, such as 3600 hours, 4200 hours, 4800 hours, or 5400 hours, with audits conducted at each 600 hour interval over 3000 hours. Similarly, a maximum test duration of more than 1800 hours for test fluids (C) and (D) may optionally be used, such as 2400 hours or 3000 hours, with audits conducted at each 600 hour interval over 1800 hours.

f. Pause the test at the audit intervals listed below, flush each pump with Indolene unleaded and measure the five pump performance parameters at this interim point in the test. Then the pumps are to be drained and returned to the tank to continue the test.

Table 2 - Durability test audit intervals

Audit Intervals for Test Fuels (A) and (B)	Audit Intervals for Test Fuels (C) and (D)
0 hours	0 hours
600 hours	600 hours
1200 hours	1200 hours
1800 hours	1800 hours (completion)
2400 hours	
3000 hours (completion)	

*See step (e) for optional maximum test durations.

g. At the completion of the listed maximum run time for the fuel being employed, each test pump shall be removed from the tank, then flushed using the standard test fluid of Indolene unleaded. Run the pump for a period of 15 minutes. Each pump shall then be tested using Indolene unleaded gasoline to ascertain the post-test values of the five key pump performance parameters of deadhead pressure, the delivered flow at rated pressure, the pump electrical resistance, the pump current draw, and pump speed at the rated delivery pressure and voltage.

h. Repeat steps (a) through (g) for the next test fuel, using another set of at least five new pumps.

9.4.4 Analysis and Data Reduction for the Operational Durability Test

Following the completion of the tests on each test fuel, disassemble and inspect at least three of the tested pumps in the set for each test fluid and note any wear that is detected. Compute the change in each of the five performance parameters from the start of the test until each indicated audit point. Convert the changes for deadhead pressure, the delivered flow at rated pressure, and the pump speed into percentage changes.

9.4.5 Data Reporting for the Operational Durability Test

Record the wear-inspection observations of the three pumps in the test set on the data reporting sheet in Table 9. Record the serial numbers of all of the pumps that were tested, indicating with an asterisk which pumps were disassembled for inspection.

In the title block of Part 5A of Table 9, record the actual maximum test durations that were used for test fuels (A) or (B), and for test fuels (C) and (D). Also in Part 5A of the data reporting sheet in Table 9, record the pre-test values for the pump flow at rated pressure, the deadhead pressure, the electrical resistance and the pump current draw and pump speed at the rated delivery pressure and voltage for each of the test fuels. Also record the values for those same parameters that were measured at each of the indicated audit points. Record the computed changes in those five values from the start of the test until each audit point is attained. Record the changes for flow, deadhead pressure, and pump speed as percentage changes. For an optional maximum test duration above 3000 hours for test fuels (A) and (B), or above 1800 hours for test fuels (C) and (D), use a copy of sheet 5A and indicate the audit duration being reported. Attach that copy.

10. DATA REPORTING SHEETS

Table 3 - SAE J1537: Data reporting sheet for fuel pump flow testing

SAE J1537: Data Reporting Sheet for Fuel Pump Flow Testing					
Part 1: General Test Logistics					
Test name or log		Date of test			
Name of operator		Time of test			
File name of data archive		Location of test			
Additional information					
Part 2: Information on the In-Tank Electric Gasoline Pump					
Pump manufacturer and design type					
Pump description					
Pump part number					
Serial numbers					
Serial numbers					
Serial numbers					
Serial numbers					
Serial numbers					
Pump rotor type and voltage					
Maximum rated fuel flow (L/h)					
Part 3: Test Conditions	**Specific Test Conditions**		**Standard Test Conditions**		
Test fluid			Indolene unleaded gasoline		
Test fluid specific gravity					
Ambient temp (°C)			21 ± 2		
Ambient press (kPa)			100 ± 5		
Fluid temp (°C)			21 ± 2		
Rated delivery pressure (kPa)			P_{NORM} ± 0.5%		
Additional information					
Part 4: Specific Instrument Information and Test Deviations					
Test deviation for serial number	Associated deviation	Test deviation for serial number	Associated deviation		
Instrument information					
Part 5A: Results from the Pre-Test or Post-Test Pump Flow Tests at Standard Conditions					
Check the type of pump flow test: □ Pre-test or □ Post-test					
SERIAL NUMBER: ______________ Rated flow and pump outlet pressure at standard test conditions:	SAE J1537 pump rated flow for standard test: __________ (L/h)	SAE J1537 pump outlet pressure for standard test: __________ (kPa)	Current draw: ________ (A) Pump speed: _______ (rpm)		
SERIAL NUMBER: ______________ Rated flow and pump outlet pressure at standard test conditions:	SAE J1537 pump rated flow for standard test: __________ (L/h)	SAE J1537 pump outlet pressure for standard test: __________ (kPa)	Current draw: ________ (A) Pump speed: _______ (rpm)		

SAE J1537: Data Reporting Sheet for Fuel Pump Flow Testing			
SERIAL NUMBER: ______________ Rated flow and pump outlet pressure at standard test conditions:	SAE J1537 pump rated flow for standard test: __________ (L/h)	SAE J1537 pump outlet pressure for standard test: __________ (kPa)	Current draw: ________ (A) Pump speed: _______ (rpm)
SERIAL NUMBER: ______________ Rated flow and pump outlet pressure at standard test conditions:	SAE J1537 pump rated flow for standard test: __________ (L/h)	SAE J1537 pump outlet pressure for standard test: __________ (kPa)	Current draw: ________ (A) Pump speed: _______ (rpm)
SERIAL NUMBER: ______________ Rated flow and pump outlet pressure at standard test conditions:	SAE J1537 pump rated flow for standard test: __________ (L/h)	SAE J1537 pump outlet pressure for standard test: __________ (kPa)	Current draw: ________ (A) Pump speed: _______ (rpm)
Observed test deviations and test comments:			
Part 5B: Data Plots			
No plots required for the pre-test and post-test flow measurements.			
Part 5C: Results from the Flow Characterization Pump Flow Tests			
Pump No _____ S/N ___________________ *Use copies of Datasheet 5C for each pump tested			
Measured flow, pump outlet press and applied voltage RUN # 1	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 12.0 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Measured flow, pump outlet press and applied voltage RUN # 2	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC Voltage for this run: 12.0 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Measured flow, pump outlet press and applied voltage RUN # 3	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 12.0 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)

SAE J1537: Data Reporting Sheet for Fuel Pump Flow Testing			
Measured flow, pump outlet press and applied voltage RUN # 4	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 13.5 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Measured flow, pump outlet press and applied voltage RUN # 5	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 13.5 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Measured flow, pump outlet press and applied voltage RUN # 6	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 13.5 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Measured flow, pump outlet press and applied voltage RUN # 7	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 9.0 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Measured flow, pump outlet press and applied voltage RUN # 8	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 9.0 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Measured flow, pump outlet press and applied voltage RUN # 9	Measured fuel flow rate of pump: __________ (L/h)	Pump outlet pressure for this run: _______ (kPa) Applied DC voltage for this run: 9.0 VDC	Current draw: ________ (A) Pump speed: _______ (rpm)
Observed test deviations, including the pump S/N and run number:			
Part 5D: Data Plots for Pump Flow Characterization			
Attach plot of measured flow versus delivery pressure for a range of applied DC voltages.			

Table 4 - SAE J1537: Data reporting sheet for temperature cycling and hot fuel handling

SAE J1537: Data Reporting Sheet for the Temperature Cycling Test and the Hot Fuel Handling Test			
Part 1: General Test Information			
Test name or log		Date of test	
Name of operator		Time of test	
File name of data archive		Location of test	
Additional information			
Part 2: Information on the In-Tank Electric Gasoline Pump			
Pump manufacturer and design type			
Pump description			
Pump part number			
Pump serial numbers			
Pump serial numbers			
Additional information			
Part 3: Test Conditions			
Test Type Being Run (Check)	Tested Temperatures if Not Standard	Standard Test Temperatures	
□ Temperature cycle □ Hot fuel handling		See profile in test procedures From -30 to +75 °C From +20 to +65 °C	
Test fuel for temperature cycle	None; pumps are tested dry		
Test fuel for hot fuel handling	Bogey II for hot fuel handling, plus Indolene for pre-test and post-test		
Additional information			
Part 4: Description and Comments on Test Equipment or Test Deviations			
Test equipment details			
Test deviations: Note any deviations from the specified conditions or procedures			
Part 5A: Results for the Temperature Cycle Test			
Performance Parameter	Pre-Test Value	Post-Test Value	Change
Pump #1 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			
Pump #2 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			

SAE J1537: Data Reporting Sheet for the Temperature Cycling Test and the Hot Fuel Handling Test			
Pump #3 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			
Pump #4 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			
Pump #5 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			
Pump #6 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			
Pump #7 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			
Pump #8 (SN):			
Flow rate at rated pressure (L/h)			%
Pump speed (rpm)			%
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			%
Comments and observations			
For testing of more than eight pumps, use additional copies of the Part 5A datasheet			

SAE J1537: Data Reporting Sheet for the Temperature Cycling Test and the Hot Fuel Handling Test						
Part 5B: Results for the Hot Fuel Handling Test						
Voltage = 12.0 VDC Target (Rated) Outlet Pressure: (kPa)	Pre-Test Indolene Test Fuel Measurements	Pre-Test Bogey II Test Fuel Measurements	Post-Test Indolene Test Fuel Measurements	% Change Pre-Test to Post-Test Indolene	% Change Pre-Test Indolene to Pre-Test Bogey II	Hot Fuel Handling Measurement Extremes (Min or Max) at Associated Temps
PUMP # 1 S/N:						
Outlet pressure (kPa)						Min °C
Flow rate (L/h)						Min °C
Current draw (A)						Min °C
Pump speed (rpm)						Max °C
PUMP # 2 S/N:						
Outlet pressure (kPa)						Min °C
Flow rate (L/h)						Min °C
Current draw (A)						Min °C
Pump speed (rpm)						Max °C
PUMP # 3 S/N:						
Outlet pressure (kPa)						Min °C
Flow rate (L/h)						Min °C
Current draw (A)						Min °C
Pump speed (rpm)						Max °C
PUMP # 4 S/N:						
Outlet pressure (kPa)						Min °C
Flow rate (L/h)						Min °C
Current draw (A)						Min °C
Pump speed (rpm)						Max °C
PUMP # 5 S/N:						
Outlet pressure (kPa)						Min °C
Flow rate (L/h)						Min °C
Current draw (A)						Min °C
Pump speed (rpm)						Max °C
For hot fuel handling testing of more than five pumps, use additional copies of the Part 5B datasheet						

SAE J1537: Data Reporting Sheet for the Temperature Cycling Test and the Hot Fuel Handling Test
Part 5C: Required Data Plots and Attachments
For each pump that is tested, attach plots of each of the four measured pump performance parameters and the test fluid temperature versus test time. These parameters are indicated in the data reporting subsection.

Table 5 - SAE J1537: Data reporting sheet for cold magnet knockdown and load dump

SAE J1537: Data Reporting Sheet for the Cold Magnet Knockdown Test and for the Load Dump Transient Test			
Part 1: General Test Logistics			
Test name or log		Date of test	
Name of operator		Time of test	
File name of data archive		Location of test	
Additional information			
Part 2: Information on Pump and Automotive Battery Type/Capacity			
Pump manufacturer and design type			
Pump description			
Pump part number			
Pump serial number			
Battery type			
Battery CCA (A)			
Additional information			
Part 3: Test Conditions			
	Specific Test Conditions	Standard Test Conditions Cold Magnetic Knockdown/Load Dump Transient	
Test fluid		Indolene unleaded gasoline	
Ambient temperature (°C)		21.0 ± 2.0	
Ambient pressure (kPa)		100 ± 5	
Fluid temperature (°C)		-35.0 ± 2.0/21 ± 2	
Initial pump temperature (°C)		-35.0 ± 2.0/21 ± 2	
Voltage application duration (seconds)		5 ± 0.1/—	
Dwell time between each of the voltage applications (seconds)		5 ± 0.1/—	
Test voltage (VDC)		24.0 ± 0.1/12.0 ± 0.1	
Pump axis orientation (degrees)		Horizontal	
Pump preconditioning time (hours)		2 ± 0.1/—	
Additional information			
Part 4: Description and Comments on Instruments or Test Deviations			
Instrument details			
Test deviations			

SAE J1537: Data Reporting Sheet for the Cold Magnet Knockdown Test and for the Load Dump Transient Test				
Part 5: Test Results for Cold Magnet Knockdown Test or Load Dump Transient Test				
Check which test is being reported: □ Cold Magnet Knockdown □ Load Dump Transient				
Test Pump Sample #	Performance Variable	Pre-Test Value at 12 VDC	Post-Test Value at 12 VDC	Change In Value
Test Pump #1	Flow rate at rated pressure	(L/h)	(L/h)	(%)
S/N = ____________	Pump speed	(rpm)	(rpm)	(%)
	Pump current draw	(A)	(A)	(A)
	Pump electrical resistance	(Ω)	(Ω)	(Ω)
	Deadhead pressure	(KPa)	(KPa)	(%)
Test Pump #2	Flow rate at rated pressure	(L/h)	(L/h)	(%)
S/N = ____________	Pump speed	(rpm)	(rpm)	(%)
	Pump current draw	(A)	(A)	(A)
	Pump electrical resistance	(Ω)	(Ω)	(Ω)
	Deadhead pressure	(KPa)	(KPa)	(%)
Test Pump #3	Flow rate at rated pressure	(L/h)	(L/h)	(%)
S/N = ____________	Pump speed	(rpm)	(rpm)	(%)
	Pump current draw	(A)	(A)	(A)
	Pump electrical resistance	(Ω)	(Ω)	(Ω)
	Deadhead pressure	(KPa)	(KPa)	(%)
Test Pump #4	Flow rate at rated pressure	(L/h)	(L/h)	(%)
S/N = ____________	Pump speed	(rpm)	(rpm)	(%)
	Pump current draw	(A)	(A)	(A)
	Pump electrical resistance	(Ω)	(Ω)	(Ω)
	Deadhead pressure	(KPa)	(KPa)	(%)
Test Pump #5	Flow rate at rated pressure	(L/h)	(L/h)	(%)
S/N = ____________	Pump speed	(rpm)	(rpm)	(%)
	Pump current draw	(A)	(A)	(A)
	Pump electrical resistance	(Ω)	(Ω)	(Ω)
	Deadhead pressure	(KPa)	(KPa)	(%)
If testing more than five pumps, or when reporting for both the cold magnet knockdown and load dump transient tests, use additional copies of this Part 5 data reporting sheet.				
Data plots	None required			

Table 6 - SAE J1537: Data reporting sheet for the optional electrical interference test

SAE J1537: Data Reporting Sheet for the Optional Electrical Interference Test Detailed in ISO 7637-2 (2011)				
Part 1: General Test Information				
Test name or log		Date of test		
Name of operator		Time of test		
File name of data archive		Location of test		
Additional information				
Part 2: Information on the In-Tank Electric Gasoline Pump				
Pump manufacturer				
Pump part number				
Pump description				
Rated flow rate (L/h)				
Rated pressure (kPa)				
Rated rpm				
Rated voltage				
Pump rotor type				
Pump serial number(s)				
Pump serial number(s)				
Additional information				
Part 3: Test Conditions				
	Specific Test Conditions	Standard Test Conditions		
Test fluid		n-heptane		
Ambient temperature (°C)		21 ± 2		
Ambient pressure (kPa)		100 ± 5		
Fluid temperature (°C)		21 ± 2		
Fuel test pressure (kPa)		P_{NORM} ±0.5%		
Test pressure tolerance		±0.5%		
Pump temperature (°C)		21 ± 2		
Part 4: Information for Specific Instruments Required in ISO 7637-2.				
Also, provide listing of any test deviations from ISO 7637-2 procedures that are encountered during the testing.				
Additional info, comments deviations, and instabilities				
Part 5: Test Results on Pulses and Measured Interference Levels as Noted in ISO 7637-2 (2011)				
Record the data required in ISO 7637-2 (2011) here				
Comments and clarifications of the reported data				

Table 7 - SAE J1537: Data reporting sheet for the vibration test

SAE J1537: Data Reporting Sheet for the Vibration Test			
Part 1: General Test Information			
Test name or log		Date of test	
Name of operator		Time of test	
File name of data archive		Location of test	
Additional information			
Part 2: Information on the In-Tank Electric Gasoline Pump			
Pump manufacturer			
Pump description			
Pump part number		Enter particular pump S/N (see Part 5 datasheet)	
Pump application voltage		None—pumps are not energized	

Part 3: Test Conditions		
	Actual Test Conditions	Standard Test Conditions
Ambient temperature (°C)		21 ± 2
Ambient pressure (kPa)		100 ± 5
Test fluid type		N/A—pumps are tested dry
Test fluid temp (°C)		N/A
Fluid test pressure (kPa)		N/A

Part 4: Description and Comments on Test Equipment or any Test Deviations	
Comments and Information	
Test Deviations present?	

Part 5: Specific Test Measurements for the Vibration Test			
Use for additional pumps as required			
Pump serial number: ______________________		Pump test unit: Number ___ of a total of _____	
Vibration Test - Pump #1	Pre-Test Value	Post-Test Value	Deviation
Flow rate—rated pressure (L/h)			(%)
Pump speed (rpm)			(%)
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			(%)
Vibration Test - Pump #2	Pre-Test Value	Post-Test Value	Deviation
Flow rate—rated pressure (L/h)			(%)
Pump speed (rpm)			(%)
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			(%)
Vibration Test - Pump #3	Pre-Test Value	Post-Test Value	Deviation
Flow rate—rated pressure (L/h)			(%)
Pump speed (rpm)			(%)
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			(%)
Vibration Test - Pump #4	Pre-Test Value	Post-Test Value	Deviation
Flow rate—rated pressure (L/h)			(%)
Pump speed (rpm)			(%)
Pump current draw (A)			(A)
Pump resistance (Ω)			(Ω)
Pump deadhead pressure (kPa)			(%)