CALIFORNIA
AIR RESOURCES BOARD

Small Off-Road Engine Evaporative Emissions Test Procedure

TP-901

Test Procedure for Determining Permeation Emissions from Small Off-Road Engine Fuel Tanks

Adopted: July 26, 2004
Amended: September 18, 2017
Amended: May 6, 2019
Amended: January 1, 2023

TP-901
Table of Contents

List of Figures

California Environmental Protection Agency
Air Resources Board

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A set of definitions common to all Certification and Test Procedures is in title 13, California Code of Regulations, section 2752 et seq.

For the purpose of this procedure, the term "CARB" refers to the California Air Resources Board, and the term "Executive Officer" refers to the CARB Executive Officer, or his or her authorized representative or designee.

1. Applicability

This Test Procedure, TP-901, is used by the California Air Resources Board to determine the permeation rate from fuel tanks of spark-ignited small off-road engines and equipment. Small off-road engines (SORE) are defined in title 13, California Code of Regulations (CCR), section 2401 et seq. This Test Procedure is proposed pursuant to Section 43824 of the California Health and Safety Code (CH&SC) and is applicable in all cases where engines or equipment with fuel tanks subject to the permeation emission standard in title 13, Cal. Code Regs., section 2754, 2755 or 2757 are sold, supplied, offered for sale, or manufactured for use in the State of California.

1.1 Requirement to Comply with All Other Applicable Codes and Regulations

Certification of a fuel tank or evaporative emission control system by the Executive Officer does not exempt the fuel tank or evaporative emission control system from compliance with other applicable codes and regulations such as state and federal safety codes and regulations.

1.2 Safety

This test procedure involves the use of flammable materials and shall only be used by or under the supervision of those familiar and experienced in the use of such materials. Appropriate safety precautions shall be observed at all times while performing this test procedure.

2. Principle and Summary of Test Procedure

This test procedure uses the corrected daily mass change or reactive organic gas (ROG) emissions measured by a flame ionization detector (FID) of five identical fuel tanks to calculate the permeation rate of each fuel tank. Prior to permeation testing of the fuel tanks, durability testing and preconditioning are performed. Durability testing exposes the fuel tanks to pressure and vacuum extremes, ultraviolet radiation, fuel sloshing, and fuel cap installation cycles. After durability testing, the fuel tanks are filled to nominal capacity with fuel and allowed to precondition to maximize the permeation emissions.

After preconditioning, the fuel tanks are placed in a temperature-controlled enclosure and exposed to a constant temperature of 40 ± 2 °C. The permeation rate is determined by one of two methods. In the first, described in section 11 of this test procedure, the mass change of each fuel tank is measured daily and corrected using an identical reference tank that does not contain fuel to calculate the permeation rate. In the second, described in section 12 of this test procedure, the ROG emissions from each tank are measured by a FID.

3. Biases and Interferences

To ensure the losses attributed to permeation are accurately quantified during this test procedure, the tanks must remain exposed to the constant 40 ± 2 °C temperature for each 24-hour (± 30 minutes) period.

Certification test fuel as specified in section 6 of this procedure is required for both preconditioning and testing.

4. Sensitivity and Range

The range of mass measurement of filled tanks is approximately 100 grams to 32,000 grams, depending on tank volume. For mass measurements more than 6200 grams, the minimum sensitivity of the balance must be 0.1 grams. For mass measurement between 1000 and 6200 grams, the minimum sensitivity of the balance must be 0.01 grams. For mass measurements less than 1000 grams, the minimum sensitivity of the balance must be 0.001 grams.

5. Equipment

(a) A balance that meets the requirements of section 4 above.

(b) A vented enclosure with a temperature conditioning system capable of controlling the internal enclosure air temperature to within ± 2.0 °C over the duration of the test. Data confirming this performance shall be recorded at a rate no slower than once every 5 minutes.

(c) A barometric pressure transducer capable of measuring atmospheric pressure to within ± 2.0 millimeters of mercury.

(d) A temperature instrument capable of measuring ambient temperature to within ± 0.2 °C.

(e) A relative humidity measuring instrument capable of measuring the relative humidity (RH) accurately to within ± 2 percent RH.

(f) Instrumentation meeting the requirements of section 4 of TP-902 (if permeation testing will be performed according to section 12 of this test procedure).

6. Certification Test Fuel

Testing according to this procedure shall be conducted using 1) LEV III Certification Gasoline as defined in part II, section A.100.3.1.2 of the *California 2015 and Subsequent Model Criteria Pollutant Exhaust Emission Standards and Test Procedures and 2017 and Subsequent Model Greenhouse Gas Exhaust Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles*, as last amended September 2, 2015, or 2) the gasoline defined in 40 CFR Part 1060.520(e).

7. Calibration Procedure

All instruments and equipment used in this procedure shall be calibrated at the time interval specified by the manufacturer or more often as needed per manufacturer instructions (e.g., if equipment undergoes repair).

The balance listed in section 5(a) shall be calibrated annually per the balance manufacturer's instructions, or more often as needed per the manufacturer instructions, using *Système International d'Unités* (SI)-traceable mass standards through National Institute of Standards and Technology (NIST) or another member of the Mutual Recognition Arrangement of the *Comité International des Poids et Mesures* (CIPM MRA). The SI-traceable mass standards shall be calibrated annually by an independent organization or more often as needed.

The instrumentation for measuring permeation emissions according to section 12 of this test procedure must be calibrated as specified in section 4 of TP-902.

8. Durability Demonstration

A durability demonstration is required prior to permeation testing. These

durability tests are designed to ensure the fuel tank assembly meets the permeation emission standard throughout the useful life of the equipment. A durability demonstration consists of the following tests:

8.1 Pressure Test

A pressure test shall be performed without fuel and prior to any other portion of the durability demonstration or preconditioning of the fuel tank.

(a) Determine the fuel tank system's design pressure and vacuum limits under normal operating and storage conditions considering the influence of any associated pressure/vacuum relief components. To do this, measure the pressure limits using a fuel tank from an evaporative emission control system that is not used for any other portion of this test procedure by installing a pressure transducer in the fuel tank. With the exception of the use of the pressure transducer and connection to a carbon canister, as applicable, the fuel tank and fuel tank configuration used for these pressure measurements shall be identical to those used in the remainder of this test procedure. Using compressed air of no less than 21 °C, pressurize the fuel tank with compressed air, seal the fuel tank, and measure the pressure every second for 5 minutes. Use a vacuum pump to draw a vacuum in the fuel tank, seal the fuel tank, and measure the pressure every second for 5 minutes. Record the maximum and minimum pressure measurements on the test report. Subsection (b) of this test is not required if the fuel tank pressure does not exceed a gauge pressure of + 1.0 kPa for at least one minute when pressurized and the fuel tank vacuum does not exceed a gauge pressure of – 1.0 kPa for at least one minute when a vacuum is drawn in the fuel tank.

(b) A pressure test shall be performed by sealing each fuel tank and cycling the pressure between + 13.8 and − 3.4 kPa (+ 2.0 and − 0.5 psig) for 10,000 cycles at a rate of 60 seconds per cycle. If normal operating or storage conditions cause pressure changes greater than + 13.8 or – 3.4 kPa to accumulate in the fuel tanks, cycle the pressure in the fuel tanks between the actual high and low pressure limits experienced during normal operation or storage. The tank pressure test shall be performed in a 49 ± 3 °C environment with compressed air of no less than 21 °C.

8.2 Slosh Test

A slosh test shall be performed by filling each fuel tank to 50 percent of its

nominal capacity with the fuel specified in section 6 of this procedure and rocking it from an angle deviation of + 15° to −15° from level at a rate of 15 cycles per minute for a total of one million total cycles. As an alternative to rocking the fuel tank, use a laboratory sample orbital shaker table or similar device to subject the tank to a centripetal acceleration of at least 2.4 meter·second^{-2} at a frequency of 2 ± 0.25 cycles per second for one million cycles. Seal all openings in each fuel tank as they would be sealed when installed on a production engine during slosh testing. A plug, cap, or coupon may be used to seal any openings to which a hose or tube is normally attached.

8.3 Ultraviolet Radiation Exposure

A sunlight-exposure test shall be performed by exposing each fuel tank to an ultraviolet light of at least 24 W·m^{-2} (0.40 W·hr·m^{-2}·min^{-1}) on the tank surface for at least 450 hours. Measure and record ultraviolet light intensity at least every hour. Alternatively, each fuel tank may be exposed to direct natural sunlight for at least 450 daylight hours. The ultraviolet radiation exposure test may be omitted if no part of the fuel tank, including the filler neck and fuel cap, will be exposed to light when installed on an engine.

8.4 Fuel Cap Installation Cycles

Installation cycles shall be performed with fuel caps intended for use with the fuel tanks by putting each fuel cap on and taking it off 300 times. Tighten the fuel cap each time in a way that represents typical usage.

8.5 Fuel Cap and Tether Spill Test

Fill the fuel tank to its nominal capacity with fresh test fuel as specified in section 6 of this procedure. Install the fuel cap. Loosen the fuel cap completely. Once the fuel cap is completely loosened, remove it and fully extend the tether, if one is used, within 2 seconds. If no tether is connected to the fuel cap, remove the fuel cap to a height of 15 centimeters above the top of the fill neck within 2 seconds. Any dripping, spraying or leaking of fuel from any part of the fuel cap or tether denotes a failure and shall be reported on the test report. Reinstall the fuel cap within one minute after removing it.

9. Preconditioning Procedure

After performing the durability tests, fill each tank to its nominal capacity with the fuel specified in section 6 of this procedure and install a production fuel cap expected to have permeation emissions at least as high as the highest-emitting fuel cap that will be used with fuel tanks from the evaporative family. Place the

tanks in a suitable vented enclosure. Record the preconditioning start date on the data sheet. Soak the tanks at a temperature that never falls below 38 °C for not less than 140 days. Measure and record the temperature at least every five minutes. Take steps to ensure that the fuel remains at nominal capacity throughout preconditioning. Accelerated preconditioning of the tanks shall not be less than 70 days and can be accomplished by soaking the tanks at an elevated temperature.

Data documenting that permeation emissions from the fuel tanks will not increase with further preconditioning must be provided for tanks soaked less than 140 days as follows: seal each fuel tank as described in section 10 of this test procedure, and either 1) perform a gravimetric permeation test on each fuel tank as described in section 11 of this procedure, and calculate the coefficient of determination, r^2, as described in section 11.(a)(8) of this test procedure; or 2) perform two permeation tests with a FID, as described in section 12 of this procedure, on each fuel tank separated by at least 15 days, and calculate the permeation rate as described in section 14 of this test procedure. The coefficient of determination for a gravimetric permeation test used to demonstrate that permeation emissions from the fuel tanks will not increase with further preconditioning must be equal to or greater than 0.95 without any rounding. The permeation rate measured in the second of two permeation tests with a FID separated by at least 15 days that are used to demonstrate permeation emissions from the fuel tanks will not increase with further preconditioning must be no greater than the permeation rate measured in the first test. Fuel tanks shall continue to be preconditioned at a temperature that never falls below 38 °C between permeation tests. The time of the durability demonstration in section 8.2 through 8.5 of this procedure may be counted as part of the preconditioning procedure if the ambient temperature remains within the specified temperature range (≥ 38 °C) and each fuel tank is at least 50 percent full; fuel may be added or replaced as needed to conduct the specified durability tests. Record the fuel fill amount and dates on the test report if fuel is added or replaced. Drain the fuel tank and refill with fresh test fuel to nominal capacity 15 days prior to ending preconditioning. The fuel tank must not be empty for more than 15 minutes. Record the date and time the fuel tank is drained and refilled with fresh test fuel, and record the fuel fill amount on the test report.

10. Sealing Procedure

(a) After preconditioning, remove the tanks from the enclosure to a well-ventilated area. Record the preconditioning end date on the data sheet. Remove the cap and empty the tanks. The tanks must not remain empty for more than fifteen minutes. Immediately refill each tank to its nominal capacity with the fuel specified in section 6 of this procedure. Seal each tank with the same fuel cap used for the durability

demonstration (except section 8.1(a)) and preconditioning procedure.

(b) A reference tank is required to correct for buoyancy effects that may occur during testing only if the fuel tanks will be tested using the gravimetric permeation test in section 11 of this test procedure. Prepare the reference tank as follows:

(1) Obtain a sixth identical fuel tank that has not previously contained fuel or any other contents that might affect its mass stability.

(2) Fill the reference tank with enough glass beads (or other inert material) so the mass of the reference tank is greater than the mass of the lightest test fuel tank and less than the mass of the heaviest test fuel tank when filled with fuel.

(3) Ensure that the inert material is dry.

(4) Seal the reference tank with a production fuel cap identical to the fuel caps used to seal the test fuel tanks.

11. Gravimetric Permeation Test

(a) Perform the following steps to test the fuel tanks for permeation emissions:

(1) Determine the fuel tank's internal surface area in square-meters, accurate to at least three significant figures. The tank internal surfaces are those surfaces that are subjected to liquid fuel or fuel vapor under normal operating conditions and have an opposing surface through the wall section that is exposed to the atmosphere. Internal webs and strengthening structures not in communication with the atmosphere are not considered internal surfaces for the purposes of this testing.

(2) Weigh each sealed test fuel tank and record the mass, date, relative humidity, barometric pressure, and time on the data sheet (Figure 1) or a similar data sheet. Place the reference tank on the balance and record the mass. Place each sealed test fuel tank on the balance and record the mass. Take this measurement within 15 minutes of sealing each test fuel tank as specified in section 10 of this procedure.

(3) Carefully place each fuel tank within a temperature-controlled room or enclosure within 30 minutes of weighing it. Do not spill or

add any fuel.

(4) Close the room or enclosure as needed to control temperatures and record the time. Steps may be taken to prevent an accumulation of hydrocarbon vapors in the room or enclosure that might affect the degree to which fuel permeates through the fuel tanks. This might simply involve passive ventilation to allow fresh air exchanges.

(5) Ensure that the measured temperature in the room or enclosure stays within the temperature range specified in paragraph (a)(7) of this section.

(6) Leave the tank in the room or enclosure for the duration of the test run.

(7) Hold the temperature of the room or enclosure at 40 ± 2 °C; measure and record the temperature at least every five minutes. Record the time when each fuel tank is removed from the room or enclosure.

(8) Measure mass loss daily by weighing each sealed test fuel tank and the reference tank. Record the mass, date, relative humidity, barometric pressure, and time on the data sheet. Calculate the cumulative mass loss in grams for each measurement using the equation in section 14(a) of this procedure. Calculate the coefficient of determination, r^2, based on a linear plot of cumulative weight loss vs. test days. Use the equation in 40 CFR 1065.602(k), with cumulative weight loss represented by y_i and cumulative time represented by y_{ref}. The daily measurements must be at approximately the same time each day. Return each fuel tank to the temperature-controlled room or enclosure within 30 minutes of removing it for weighing. Up to two daily measurements may be omitted in any seven-day period. Test for ten full days, then determine when to stop testing as follows:

(i) Testing of a fuel tank may be stopped after the measurement on the tenth day if r^2 is at or above 0.95 or if the measured permeation rate is less than 50 percent of the applicable standard and the upper limit of the 95 percent confidence interval, as calculated in section 14(d) of this procedure, of the mean permeation rate for the fuel tank is below the applicable standard.

(ii) If, after ten days of testing, r^2 is below 0.95 and the

measured permeation rate is more than 50 percent of the applicable standard or the upper limit of the 95 percent confidence interval of the mean permeation rate for the fuel tank is above the applicable standard, continue testing for a total of 20 days or until r^2 is at or above 0.95. If r^2 is not at or above 0.95 within 20 days of testing, discontinue the test and precondition the fuel tank further until it has stabilized permeation emission levels, then repeat the testing.

(9) Calculate the difference in mass between the reference tank and each test fuel tank for each daily measurement. This value is M_i, where i is a counter representing the number of days elapsed.

(10) Determine the final permeation rate based on the cumulative mass loss measured on the final day of testing using the equation in section 14(e). Round this result to the same number of decimal places as the emission standard.

12. Permeation Test with Flame Ionization Detector

(a) Perform the following steps to test each fuel tank for permeation emissions:

(1) Determine the fuel tank's internal surface area in square-meters, accurate to at least three significant figures. The tank internal surfaces are those surfaces that are subjected to liquid fuel or fuel vapor under normal operating conditions and have an opposing surface through the wall section that is exposed to the atmosphere. Internal webs and strengthening structures not in communication with the atmosphere are not considered internal surfaces for the purposes of this testing.

(2) Place the fuel tank in an enclosure meeting the requirements of section 4 of TP-902 that is equilibrated to 40 ± 2 °C, and close the enclosure within 15 minutes of sealing the fuel tank as specified in section 10 of this procedure.

(3) Purge the enclosure to reduce the reactive organic gas concentration and perform a 24-hour permeation test at a constant temperature of 40 ± 2 °C. Measure the reactive organic gas emissions from the fuel tank using a flame ionization detector meeting the requirements of section 4 of TP-902.

13. Recording Data

Record data on data sheet shown in figure 1 or a similar data sheet.

14. Calculations

(a) The cumulative daily mass loss in grams for each test fuel tank is calculated for each 24-hour cycle as follows:

cumulative mass loss = $M_0 - M_i$

Where
M_0 = initial difference in mass between a test fuel tank and the reference tank;
M_i = difference in mass between a test fuel tank and the reference tank after permeation testing for i days.

(b) Calculate the daily mass loss as follows:

daily mass loss = $M_i - M_{i-1}$

Where
M_{i-1} = difference in mass between a test fuel tank and the reference tank after permeation testing for (i – 1) days.

(c) Calculate the daily permeation rate, P_i, for a test fuel tank as follows:

$$P_i = \frac{\text{daily mass loss}}{SA \cdot 1 \text{ day}}$$

Where
SA = the internal surface area of the fuel tank

(d) Calculate the upper limit of the 95 percent confidence interval for the mean permeation rate of each test fuel tank as follows:

$$\text{Upper limit of 95 percent CI} = \overline{P} + \frac{ts}{\sqrt{N}}$$

Where
P = mean daily permeation rate for a test fuel tank;
t = Student's critical t value for 95 percent confidence (e.g., 2.262 for 10 measurements);
s = sample standard deviation of the mean,

$$\sqrt{\frac{\sum_{i=1}^{N}(P_i-\bar{P})^2}{N-1}};$$

N = number of measurements.

(e) Calculate the final permeation rate, P, for a test fuel tank tested according to section 11 of this test procedure as follows:

$$P = \frac{\text{cumulative mass loss}}{SA \cdot i}$$

Where
i = number of days of permeation testing for a test fuel tank.

(f) Calculate the permeation rate for a fuel tank tested according to section 12 of this test procedure as described in section 5.5 of TP-902 for diurnal emissions, using the actual test volume of the fuel tank assembly as tested instead of the volume of an engine or equipment unit.

15. Alternative Test Procedures

Test procedures, other than specified above, shall only be used if prior written approval is obtained from the CARB Executive Officer. In order to secure the CARB Executive Officer's approval of an alternative test procedure, the applicant is responsible for demonstrating to the CARB Executive Officer's satisfaction that the alternative test procedure is equivalent to this test procedure.

16. Figures

Figure 1. Data Sheet

Figure 1. Data Sheet

Tank Manufacturer:
Tank I.D:
Tested By:
Tank Internal Surface Area (meter^2):

Full Tank Data

Date/Time Start		Date/Time End		Initial Mass (grams)	Final Mass (grams)	Difference (grams)	Mass Loss (grams)

Reference Tank Data

Date/Time Start		Date/Time End		Initial Mass (grams)	Final Mass (grams)	Difference (grams)	%RH	Baro. Pres.