Appendix D

Proposed Amendments to Small Off-Road Engine Evaporative Emissions Test Procedure, TP-902, Test Procedure for Determining Evaporative Emissions from Small Off-Road Engines

(Note: The Proposed Amendments are shown in underline to indicate additions and ~~strikeout~~ to indicate deletions from the existing regulatory text. Final page numbers subject to change upon Office of Administrative Law approval.)

CALIFORNIA AIR RESOURCES BOARD

Small Off-Road Engine Evaporative Emissions Test Procedure

TP-902

Test Procedure for Determining Evaporative ~~Diurnal~~ Emissions from Small Off-Road Engines

Adopted: July 26, 2004
Amended: September 18, 2017
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TP-902

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California Environmental Protection Agency
Air Resources Board

Small Off-Road Engine Evaporative Emissions Test Procedure

TP-902

Test Procedure for Determining Evaporative Diurnal Emissions from Small Off-Road Engines

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 designate designee.

1. APPLICABILITYApplicability

This Test Procedure, TP-902, is used by the California Air Resources Board to determine the hot soak, diurnal, and resting loss evaporative emissions from small off-road engines. Small off-road engines are defined in title 13, Cal. Code Regs., 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 small off-road engines 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 an evaporative emission control system by the Executive Officer does not exempt the 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. ~~PRE-CERTIFICATION REQUIREMENTS~~Pre-Certification Requirements

2.1 Durability Demonstration

A durability demonstration shall be performed on the evaporative emission control system of a test engine prior to its ~~diurnal~~ evaporative emission test. The durability demonstration shall include the following tests:

(a) Actuate all control valves, cables, and linkages, where applicable, for a minimum of 5000 cycles. Install and remove the fuel cap 300 times. Tighten the fuel cap each time in a way that represents the typical in-use experience.

(b) Pressure Test

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

(1) 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 and the evaporative emission control system in which it is used shall be identical to those used on the engine tested 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 (2) 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.

(2) A pressure test shall be performed by sealing the 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 tank between the actual high and low pressure limits experienced during normal operation or storage. ~~If the fuel tank has no features that would cause positive or negative pressure to accumulate during normal operation or storage, then a pressure test is not required.~~ The tank pressure test shall be performed in a 49 ± 3 °C environment with compressed air of no less than 21 °C.

(c) Slosh Test

A slosh test shall be performed by filling the fuel tank to 50 percent of its nominal capacity with the fuel specified in section 6 of this procedure, installing the fuel cap, and rocking the fuel tank 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. If the slosh test cannot be completed with the fuel tank installed in the test unit, the fuel tank may be removed for the duration of the slosh test and installed in the test unit again after the slosh test. Openings in the fuel tank shall be sealed in the same manner as when the fuel tank is installed in the test unit.

(d) For systems that utilize a carbon canister, the durability demonstration shall include thermal cycling and vibration exposure of the canister.

(1) For thermal cycling, the test must subject the canister to 100 cycles of the following temperature profile:

(A) Heat and hold at 60 ± 2 °C for 30 minutes. (Up to 10 minutes is allowed for the temperature to rise and stabilize.)

(B) Cool and hold at 0 ± 2 °C for 30 minutes. (Up to 20 minutes is allowed for the temperature to reach 0 °C during the cooling period.)

(2) For vibration exposure, at a minimum, the canister must be placed in a suitable test fixture while maintaining its specified orientation (as designed). Subject the fixture to a peak horizontal acceleration of 4.5g × 60Hz × 10^7 times, where g is the acceleration due to Earth's gravity, 9.8 $m \cdot s^{-2}$.

(e) Ultraviolet Radiation Exposure

A sunlight-exposure test shall be performed by exposing each test engine or equipment unit to an ultraviolet light of at least 24 $W \cdot m^{-2}$ (0.40 $W \cdot hr \cdot m^{-2} \cdot min^{-1}$) for at least 450 hours. Measure and record ultraviolet light intensity at least every hour. Alternatively, each test engine or equipment unit 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 evaporative emissions control system will be exposed to light when installed on an engine.

(f) 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.

2.2 Canister Working Capacity

(a) For evaporative emission control systems that use a carbon canister and do not pressurize the fuel tank, the carbon canister must have a working capacity of at least 1.4 grams of vapor storage capacity per liter of fuel tank ~~nominal~~ total capacity for tanks greater than or equal to 3.78 liters, and 1.0 grams of vapor storage capacity per liter of fuel tank ~~nominal~~ total capacity for tanks less than 3.78 liters. For evaporative emission control systems that use a carbon canister and pressurized fuel tank, the working capacity must be specified by the applicant. For all systems utilizing actively-~~-~~purged carbon canisters, running loss emissions must be controlled from being emitted into the atmosphere.

(b) Working capacity is determined following the procedure in Attachment 1 of this test procedure. In lieu of the loading and purge rates specified in Attachment 1, the canister manufacturer's maximum loading and purge rates may be used.

2.3 Engine Purge

If a canister is used, the engine must actively purge the canister when the engine is running.

2.4 Running Loss Emission Control Test

(a) For an evaporative emission control system that does not use an actively-purged carbon canister meeting the requirements of this Test Procedure, TP-902, a running loss emission control test shall be performed using one of the following methods:

(1) Perform this sequence in order to ensure integrity of the test. The mass of the trap canister must not increase during the running loss emission control test. If the carbon canister is integrated into the fuel cap, carbon canister shall mean fuel cap only for this subsection (1). Record all measurements in the test report.

(i) Fill the fuel tank to nominal capacity and install the fuel cap;
(ii) Within 15 minutes of completion of step (i) weigh the carbon canister;
(iii) Within 15 minutes of completion of step (ii) install the carbon canister;
(iv) Within 30 minutes of completion of step (iii) expose the engine with the carbon canister installed to three 24-hour diurnal cycles as defined in Table 5-1 in section 5.4 of this Test Procedure;
(v) Within 15 minutes of completion of step (iv), weigh the carbon canister and a secondary (trap) canister;
(vi) Within 15 minutes of completion of step (v), install the carbon canister and the secondary (trap) canister in series on the engine;
(vii) Within 60 minutes of completion of step (vi), run the engine at full load (100% of rated torque) until the fuel tank is empty;
(viii) Within 15 minutes of completion of step (vii), weigh the carbon canister and the trap canister; or

(2) Perform this sequence in order to ensure integrity of the test. Data from a pressure transducer in the fuel tank must show that the pressure in the fuel tank is less than ambient pressure throughout the entire running loss test. Record all measurements in the test report.

(i) Install a pressure transducer in the fuel tank;
(ii) Fill the fuel tank to nominal capacity and install the fuel cap;
(iii) Within 60 minutes of completion of step (ii), run the engine at full load (100% of rated torque) until the fuel tank is empty, measuring ambient pressure and pressure in the fuel tank once per second throughout the sequence.

3. ~~GENERAL SUMMARY OF TEST PROCEDURE~~General Summary of Test Procedure

A Sealed Housing for Evaporative Determination (SHED) is used to measure ~~diurnal~~ evaporative emissions. This method subjects test engines to a preprogrammed temperature profile while maintaining a constant pressure and continuously sampling for hydrocarbons with a Flame Ionization Detector (FID). The volume of a SHED enclosure can be accurately determined. The mass of total organic material hydrocarbon equivalent that emanates from a test engine over the test period is calculated using the ideal gas equation.

This test procedure measures hot soak and diurnal emissions from engines or equipment with complete evaporative emission control systems as defined in title 13, Cal. Code Regs., section 2752 (a)~~(7)~~ (9) by subjecting them to a hot soak and diurnal test sequence. The engine with complete evaporative emission control system can be tested without the equipment chassis. The basic process is as follows:

- Fill the engine fuel tank with fuel and operate at maximum governed speed for 5-minutes
- Precondition the evaporative emission control system
- Drain and fill fuel tank to 50% capacity with California certification fuel
- Operate engine at the maximum governed speed for fifteen minutes
- Subject engine/equipment to a one-hour constant 35 or 40.6 °C hot soak
- Soak engine/equipment for two hours at 18.3 °C
- Subject engine/equipment to a 24-hour variable 18.3 °C – 40.6 °C – 18.3 °C (65 °F - 105 °F - 65 °F) temperature diurnal profile

The mass of total organic material hydrocarbon equivalent measured by the SHED over the hot soak and 24-hour diurnal profile is compared with the hot soak plus diurnal emission standards in title 13, Cal. Code Regs., section 2754. Engines or equipment with emissions below the appropriate hot soak plus diurnal emission standard shall be considered compliant.

4. ~~INSTRUMENTATION~~Instrumentation

The instrumentation necessary to perform evaporative emission testing for small off-road engines is the same instrumentation used for passenger cars and light duty vehicles, and is described in Title 40 of the Code of Federal Regulations (40 CFR) 86.107-98. For the purposes of this section 4, methanol shall mean ethanol and CH_3OH shall mean C_2H_5OH when testing with ethanol-containing fuel. Ethanol measurements in this test procedure may be omitted if the hydrocarbon mass calculated for the hot soak and diurnal emission tests in section 5.5 is multiplied by 1.08 as described in Part III.D.11. of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles," as last amended September 2, 2015.

4.1 Diurnal Evaporative Emission Measurement Enclosure

The diurnal evaporative emissions measurement enclosure shall be equipped with an internal blower or blowers coupled with an air temperature management system (typically air to water heat exchangers and associated programmable temperature controls) to provide for air mixing and temperature control. The blower(s) shall provide a nominal total flow rate of 0.8 ± 0.2 ft^3/min per ft^3 of the nominal enclosure volume, V_n. The inlets and outlets of the air circulation blower(s) shall be configured to provide a well-dispersed air circulation pattern that produces effective internal mixing and avoids significant temperature or hydrocarbon and alcohol stratification. The discharge and intake air diffusers in the enclosure shall be configured and adjusted to eliminate localized high air velocities which could produce non-representative heat transfer rates between the engine fuel tank(s) and the air in the enclosure. The air circulation blower(s), plus any additional blowers if required, shall maintain a homogeneous mixture of air within the enclosure.

The enclosure temperature shall be taken with thermocouples located 3 feet above the floor at the approximate mid-length of each side wall of the enclosure and within 3 to 12 inches of each side wall. The temperature conditioning system shall be capable of controlling the internal enclosure air temperature to follow the prescribed temperature versus time cycle as specified in 40 CFR §86.133-90 as modified by section III.D.10. (diurnal breathing loss test) of the "California Evaporative Emission Standards and

Test Procedures for 2001 and Subsequent Model Motor Vehicles," as last amended September 2, 2015, within an instantaneous tolerance of ± 3.0_°F and an average tolerance of ± 2.0_°F as measured by side wall thermocouples. The control system shall be tuned to provide a smooth temperature pattern, which has a minimum of overshoot, hunting, and instability about the desired long-term temperature profile.

The enclosure shall be of sufficient size to contain the test equipment with personnel access space. It shall use materials on its interior surfaces which do not adsorb or desorb hydrocarbons, or alcohols (if the enclosure is used for alcohol-fueled vehicles). The enclosure shall be insulated to enable the test temperature profile to be achieved with a heating/cooling system, which has minimum surface temperatures in the enclosure no less than 25.0_°F below the minimum diurnal temperature specification. The enclosure shall be equipped with a pressure transducer with an accuracy and precision of ± 0.1 inches H_2O. The enclosure shall be constructed with a minimum number of seams and joints, which provide potential leakage paths. Particular attention shall be given to sealing and gasketing of such seams and joints to prevent leakage.

The enclosure shall be equipped with features, which provide for the effective enclosure volume to expand and contract in response to both the temperature changes of the air mass in the enclosure, and any fluctuations in the ambient barometric pressure during the duration of the test. Either a variable volume enclosure or a fixed volume enclosure may be used for ~~diurnal~~ evaporative emission testing.

A variable volume enclosure shall have the capability of latching or otherwise constraining the enclosed volume to a known, fixed value, V_n. The V_n shall be determined by measuring all pertinent dimensions of the enclosure in its latched configuration, including internal fixtures, based on a temperature of 84_°F, to an accuracy of ± 1/8 inch (0.5 cm) and calculating the net V_n to the nearest 1 ft^3. In addition, V_n shall be measured based on a temperature of 65_°F and 105_°F. The latching system shall provide a fixed volume with an accuracy and repeatability of $0.005xV_n$. Two potential means of providing the volume accommodation capabilities are; a moveable ceiling which is joined to the enclosure walls with a flexure, or a flexible bag or bags of Tedlar or other suitable materials, which are installed in the enclosure and provided with flowpaths which communicate with the ambient air outside the enclosure. By moving air into and out of the bag(s), the contained volume can be adjusted dynamically. The total enclosure volume accommodation shall be sufficient to balance the volume changes produced by the difference between the extreme enclosure temperatures and the ambient laboratory temperature with the addition of a superimposed barometric pressure change of 0.8 in. Hg. A minimum total volume accommodation range of ± $0.07xV_n$ shall be used. The action of the enclosure volume accommodation system shall limit the differential between the enclosure internal pressure and the external ambient barometric pressure to a maximum value of ± 2.0 inches H_2O.

The fixed volume enclosure shall be constructed with rigid panels that maintain a fixed enclosure volume, which shall be referred to as V_n. V_n shall be determined by measuring all pertinent dimensions of the enclosure including internal fixtures to an accuracy of ± 1/8 inch (0.5 cm) and calculating the net V_n to the nearest 1 ft^3. The enclosure shall be equipped with an outlet flow stream that withdraws air at a low, constant rate and provides makeup air as needed, or by reversing the flow of air into and out of the enclosure in response to rising or falling temperatures. If inlet air is added continuously throughout the test, it must be filtered with activated carbon to provide a relatively constant hydrocarbon and alcohol level. Any method of volume accommodation shall maintain the differential between the enclosure internal pressure and the barometric pressure to a maximum value of ± 2.0 inches of water. The equipment shall be capable of measuring the mass of hydrocarbon, and alcohol (if the enclosure is used for alcohol-fueled equipment) in the inlet and outlet flow streams with a resolution of 0.01 gram. A bag sampling system may be used to collect a proportional sample of the air withdrawn from and admitted to the enclosure. Alternatively, the inlet and outlet flow streams may be continuously analyzed using an on-line Flame Ionization Detector (FID) analyzer and integrated with the flow measurements to provide a continuous record of the mass hydrocarbon and alcohol removal.

An online computer system or strip chart recorder shall be used to record the following parameters during the diurnal evaporative emissions test sequence:

- Enclosure internal air temperature
- Diurnal ambient air temperature specified profile as defined in 40 CFR §86.133-90 as modified in section III.D.10 of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles," as last amended September 2, 2015, (diurnal breathing loss test).
- Enclosure internal pressure
- Enclosure temperature control system surface temperature(s)
- FID output voltage recording the following parameters for each sample analysis:
  - zero gas and span gas adjustments
  - zero gas reading

– enclosure sample reading
– zero gas and span gas readings

The data recording system shall have a time resolution of 30 seconds and shall provide a permanent record in either magnetic, electronic or paper media of the above parameters for the duration of the test.

Other equipment configurations may be used if approved in advance by the Executive Officer. The Executive Officer shall approve alternative equipment configurations if the manufacturer demonstrates that the equipment will yield test results equivalent to those resulting from use of the specified equipment.

4.2 Calibrations

Evaporative emission enclosure calibrations are specified in 40 CFR §86.117-90. Amend 40 CFR §86.117-90 to include an additional subsection 1.1, to read:

The diurnal evaporative emission measurement enclosure calibration consists of the following parts: initial and periodic determination of enclosure background emissions, initial determination of enclosure volume, and periodic hydrocarbon (HC) and ethanol retention check and calibration. Calibration for HC and ethanol may be conducted in the same test run or in sequential test runs.

4.2.1 The initial and periodic determination of enclosure background emissions shall be conducted according to the procedures specified in 40 CFR §86.117-90(a)(1) through (a)(6). The enclosure shall be maintained at a nominal temperature of 105.0 °F throughout the four-hour period. Variable volume enclosures may be operated either in the latched volume configuration, or with the variable volume feature active. Fixed volume enclosures shall be operated with inlet and outlet flow streams closed. The allowable enclosure background emissions of HC and/or ethanol as calculated according to 40 CFR §86.117-90(a)(7) shall not be greater than 0.05 grams in 4 hours. The enclosure may be sealed and the mixing fan operated for a period of up to 12 hours before the initial HC concentration reading (C_{HCi}) and the initial ethanol concentration reading ($C_{C_2H_5OH_i}$) is taken and the four-hour background measurement period begins.

4.2.2 The initial determination of enclosure internal volume shall be performed according to the procedures specified in section III.A.1.3. of the "California Evaporative Emission Standards and Test

Procedures for 2001 and Subsequent Model Motor Vehicles," as last amended September 2, 2015. If the enclosure will be used for hot soak determination, the determination of enclosure internal volume shall also be performed based on 105˚F.

4.2.3 The HC and ethanol measurement and retention checks shall evaluate the accuracy of enclosure HC and ethanol mass measurements and the ability of the enclosure to retain trapped HC and ethanol. The check shall be conducted over a 24-hour period with all of the normally functioning subsystems of the enclosure active. A known mass of propane and/or ethanol shall be injected into the enclosure and an initial enclosure mass measurement(s) shall be made. The enclosure shall be subjected to the temperature cycling specified in section III.D.10.3.7 of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles," as last amended September 2, 2015, (revising 40 CFR §86.133-90(l)) for a 24-hour period. The temperature cycle shall begin at 105°F (hour 11) and continue according to the schedule until a full 24-hour cycle is completed. A final enclosure mass measurement(s) shall be made. The following procedure shall be performed prior to the introduction of the enclosure into service and following any modifications or repairs to the enclosure that may impact the integrity of this enclosure; otherwise, the following procedure shall be performed on a monthly basis. (If six consecutive monthly retention checks are successfully completed without corrective action, the following procedure may be determined quarterly thereafter as long as no corrective action is required.)

(A) Zero and span the HC analyzer.

(B) Purge the enclosure with atmospheric air until a stable enclosure HC level is attained.

(C) Turn on the enclosure air mixing and temperature control system and adjust it for an initial temperature of 105.0˚F and a programmed temperature profile covering one diurnal cycle over a 24 hour period according to the profile specified in section III.D.10.3.7. Of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles," as last amended September 2, 2015, (revising 40 CFR §86.133-90). Close the enclosure door. On variable volume enclosures, latch the enclosure to the enclosure volume measured at 105_°F. On fixed volume enclosures, close the outlet and inlet flow streams.

(D) When the enclosure temperature stabilizes at 105.0_°F ± 3.0_°F seal the enclosure; measure the enclosure background HC concentration (C_{HCe1}) and/or background ethanol concentration ($C_{C_2H_5OH1}$) and the temperature (T_1), and pressure (P_1) in the enclosure.

(E) Inject into the enclosure a known quantity of propane between 0.50 to 1.00 grams and/or a known quantity of ethanol in gaseous form between 0.50 to 1.00 grams. The injection method shall use a critical flow orifice to meter the propane and/or ethanol at a measured temperature and pressure for a measured time period. Techniques that provide an accuracy and precision of ± 0.5 percent of the injected mass are also acceptable. Allow the enclosure internal HC and/or ethanol concentration to mix and stabilize for up to 300 seconds. Measure the enclosure HC concentration (C_{HCe2}) and/or the enclosure ethanol concentration ($C_{C_2H_5OH2}$). For fixed volume enclosures, measure the temperature (T_2) and pressure in the enclosure (P_2). On variable volume enclosures, unlatch the enclosure. On fixed volume enclosures, open the outlet and inlet flow streams. Start the temperature cycling function of the enclosure air mixing and temperature control system. These steps shall be completed within 900 seconds of sealing the enclosure.

(F) For fixed volume enclosures, calculate the initial recovered HC mass (M_{HCe1}) according to the following formula:

$$M_{HCe1} = (3.05 \times V \times 10^{-4} \times [P_2 (C_{HCe2} - rC_{C_2H_5OH2})/T_2 - P_1 (C_{HCe1} - rC_{C_2H_5OH1})/T_1])$$

Where:

V is the enclosure volume at 105_°F (ft^3)
P_1 is the enclosure initial pressure (inches Hg absolute)
P_2 is the enclosure final pressure (inches Hg absolute)
C_{HCen} is the enclosure HC concentration at event n (ppm C)

$C_{C_2H_5OHn}$ is the enclosure ethanol concentration calculated according to 40 CFR §86.117-90 (d)(2)(iii) at event n (ppm C)
r is the FID response factor to ethanol
T_1 is the enclosure initial temperature (˚R)
T_2 is the enclosure final temperature (˚R)

For variable volume enclosures, calculate the initial recovered HC mass and initial recovered ethanol mass according to the equations used above except that P_2 and T_2 shall equal P_1 and T_1.

Calculate the initial recovered ethanol mass ($M_{C_2H_5OH1}$) according to 40 CFR §86.117-96(d)(1), as amended March 24, 1993.

If the recovered HC mass agrees with the injected mass within 2.0 percent and/or the recovered ethanol mass agrees with the injected mass within 6.0 percent, continue the test for the 24 hour temperature cycling period. If the recovered mass differs from the injected mass by greater than the acceptable percentage(s) for HC and/or ethanol, repeat the enclosure concentration measurement in step (E) and recalculate the initial recovered HC mass (M_{HCe1}) and/or ethanol mass ($M_{C_2H_5OH1}$). If the recovered mass based on the latest concentration measurement agrees within the acceptable percentage(s) of the injected mass, continue the test for the 24-hour temperature cycling period and substitute this second enclosure concentration measurement for C_{HCe2} and/or $C_{C_2H_5OH2}$ in all subsequent calculations. In order to be a valid calibration, the final measurement of C_{HCe2} and $C_{C_2H_5OH2}$ shall be completed within the 900-second time limit outlined above. If the discrepancy persists, the test shall be terminated and the cause of the difference determined, followed by the correction of the problems(s) and the restart of the test.

(G) At the completion of the 24-hour temperature cycling period, measure the final enclosure HC concentration (C_{HCe3}) and/or the final enclosure ethanol concentration ($C_{C_2H_5OH3}$). For fixed-volume enclosures, measure the final pressure (P_3) and final temperature (T_3) in the enclosure.

For fixed volume enclosures, calculate the final recovered HC mass (M_{HCe2}) as follows:

$$M_{HCe2} = [3.05 \times V \times 10^{-4} \times (P_3 (C_{HCe3} - rC_{C_2H_5OH3})/T_3 - P_1 (C_{HCe1} - rC_{C_2H_5OH1})/T_1)] + M_{HC,out} - M_{HC,in}$$

Where:

V is the enclosure volume at 105_°F (ft^3)

P_1 is the enclosure initial pressure (inches Hg absolute)
P_3 is the enclosure final pressure (inches Hg absolute)
C_{HCe3} is the enclosure HC concentration at the end of the 24-hour temperature cycling period (ppm C)
$C_{C_2H_5OH3}$ is the enclosure ethanol concentration at the end of the 24-hour temperature cycling period, calculated according to 40 CFR §86.117-90 (d)(2)(iii) (ppm C)
r is the FID response factor to ethanol
T_1 is the enclosure initial temperature (°R)
T_3 is the enclosure final temperature (˚R)
$M_{HC,out}$ is mass of HC exiting the enclosure, (grams)
$M_{HC,in}$ is mass of HC entering the enclosure, (grams)

For variable volume enclosures, calculate the final recovered HC mass and final recovered ethanol mass according to the equations used above except that P_3 and T_3 shall equal P_1 and T_1, and $M_{HC, out}$ and $M_{HC, in}$ shall equal zero.

Calculate the final recovered ethanol mass ($M_{C_2H_5OH2}$) according to 40 CFR §86.117-96(d)(1), as amended March 24, 1993.

(H) If the calculated final recovered HC mass for the enclosures is not within 3 percent of the initial enclosure mass, or if the calculated final recovered ethanol mass for the enclosures is not within 6 percent of the initial enclosure mass, then action shall be required to correct the error to the acceptable level.

4.3 Other Instruments and Equipment

All instruments and equipment used in this Test Procedure, TP-902, 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).

For mass measurements more than 6,200 grams, the minimum sensitivity of the balance must be 0.1 grams. For mass measurement between 1,000 and 6,200 grams, the minimum sensitivity of the balance must be 0.01 grams. For mass measurements less than 1,000 grams, the minimum sensitivity of the balance must be 0.001 grams.

The balance shall be calibrated annually per the balance manufacturer's instructions, or more often as needed per the manufacturer instructions (e.g., if the balance is moved), using *Système International d'Unités* (SI)-traceable mass standards through National Institute of Standards and

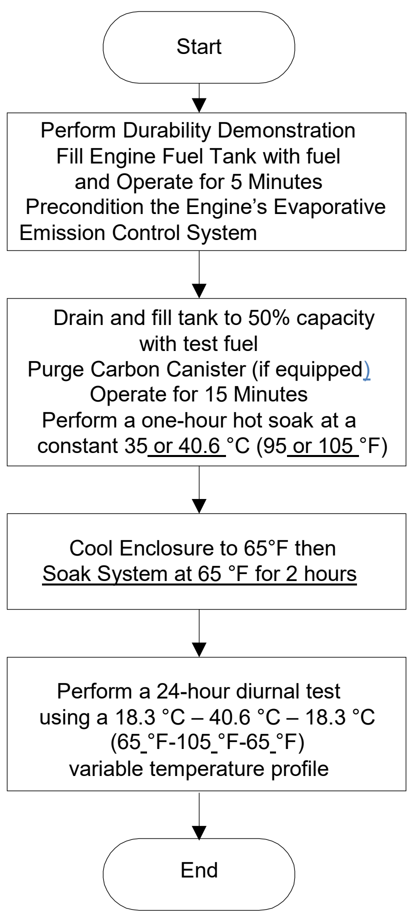
Technology (NIST) or another member of the Mutual Recognition Arrangement of the *Comité International des Poids et Mesures* (CIPM MRA). The SI-traceable mass standards shall be calibrated annually by an independent organization or more often as needed.

5. TEST PROCEDURETest Procedure

The test sequence is shown graphically in Figure 1. The temperatures monitored during testing shall be representative of those experienced by the equipment. The equipment shall be approximately level during all phases of the test sequence to prevent abnormal fuel distribution. The temperature tolerance of a soak period may be waived for up to 10 minutes to allow purging of the enclosure or transporting the equipment into the enclosure.

The 24-hour diurnal test sequence is shown in Figure 1.

Figure 1. 24-Hour Diurnal Test Sequence



5.1 Evaporative Emission Control System Preconditioning

The purpose of the preconditioning period is to introduce gasoline into the evaporative emission control system and precondition all evaporative emission control system components. Precondition the evaporative emission control system by filling the fuel tank to its nominal capacity with fresh test fuel as specified in Section 6 of this procedure. After filling the tank, start the engine and allow it to run at maximum governed speed (unloaded or blade load) for approximately five minutes. Stop the engine and add fuel to fill the fuel tank to its nominal capacity. Soak the evaporative emission control system at 30 ± 10 °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. As an alternative, accelerated preconditioning of the evaporative emission control system can be accomplished by soaking at an elevated temperature. Accelerated preconditioning shall not be less than 70 days. Data documenting that the hot soak and diurnal emissions will not increase with further preconditioning must be provided for tanks soaked less than 140 days as follows: perform the test sequence in sections 5.2 through 5.4 twice, separated by at least 15 days, and calculate hot soak and diurnal emissions as described in section 5.5 of this procedure. The hot soak and diurnal emissions measured in the second test sequence must be no higher than the hot soak and diurnal emissions measured in the first test sequence to demonstrate that the hot soak and diurnal emissions will not increase with further preconditioning. The fuel tank shall be filled to nominal capacity and the evaporative emission control system shall continue to be preconditioned at the elevated temperature between the test sequences. Record the preconditioning temperature on the test report. The period of slosh testing and ultraviolet radiation exposure may be considered part of the preconditioning period provided the ambient temperature remains within the specified temperature range 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 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 fuel, and record the fuel fill amount on the test report.

5.2 Refueling and Hot Soak

Following the preconditioning period, drain the fuel tank and refill to 50 percent of its nominal capacity with test fuel. 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 fuel, and record the fuel fill amount on the test report. For evaporative emission control systems that use ~~a~~ an actively-purged carbon canister, the canister must be purged following the preconditioning period but prior to initiating the hot soak test. Prior to purging the carbon canister, measure and record the carbon canister mass on the test report. Purging for an actively-purged carbon canister consists of drawing 400 bed volumes of ~~nitrogen or dry~~ air through the canister at the canister manufacturer's recommended purge rate. For evaporative emission control systems that use a passively-purged carbon canister, purging occurs due to vacuum created in the fuel tank when the engine is run in this section 5.2 and during forced cooling in section 5.3 of this procedure. Measure and record the carbon canister mass on the test report after purging.

Perform a tilt sequence by rotating the test unit in three of the following four directions with respect to the plane on which the test unit sits and leaving the test unit in each position for 5 minutes: 90° forward, 90° backwards, 90° to the left, and 90° to the right. It is not required to tilt the engine in the direction which results in the air inlet of the engine pointing downward. This tilt sequence may be omitted for a test unit with displacement greater than or equal to 225 cc if engines from the evaporative family will not be used in equipment that is designed to be tilted during operation, transport, maintenance, or storage. Any fuel leaking from any part of the engine or evaporative emission control system denotes a failure and shall be reported on the test report. Measure and record the carbon canister mass on the test report after performing this tilt sequence.

Operate the engine at its maximum governed speed for fifteen minutes. If the engine runs out of fuel during the fifteen minute run, restart this section 5.2 and fill the fuel tank to nominal capacity rather than 50 percent of nominal capacity. Immediately place the engine in the SHED enclosure preheated to 35 °C. The enclosure shall be configured to provide an internal enclosure ambient temperature of 35 ± 5.6 °C for the first 5 minutes, and 35 ± 2.8 °C (35 ± 1.1 °C on average) for the remainder of the hot soak test. The hot soak enclosure doors shall be closed and sealed within 180 seconds of engine shutdown. Record the time elapsed between engine shutdown and the start of the hot soak on the test report. Perform a one-hour hot soak at a constant 35 °C. The one-hour hot soak may alternatively be performed at 40.6 °C. If the hot soak is performed at 40.6 °C, the enclosure shall be configured to provide an internal enclosure ambient temperature of 40.6 ± 5.6 °C for the first 5 minutes, and 40.6 ± 2.8 °C (40.6 ± 1.1 °C on average) for the remainder of the hot soak test. The hot soak enclosure doors shall be closed and sealed within 180 seconds of engine shutdown.

Record the time elapsed between engine shutdown and the start of the hot soak on the test report.

5.3 Forced Cooling

After the hot soak test, purge the enclosure to reduce the hydrocarbon concentration to background levels. Cool the enclosure to attain a wall temperature of 18.3 °C. After cooling the enclosure to 18.3 °C, soak the engine in the enclosure for two hours at 18.3 °C.

5.4 24-Hour Diurnal Test

Immediately after soaking for two hours at 18.3 °C, purge the enclosure to reduce the hydrocarbon concentration to background levels and perform a 24-hour diurnal test using the temperature profile shown in Table 5-1. Measure and record the carbon canister mass after the diurnal test on the test report.

Table 5-1. Diurnal Temperature Profile

Hour	0	1	2	3	4	5	6	7	8	9	10	11	12
(°C)	18.3	19.2	22.6	26.8	30.1	32.6	34.8	36.7	38.4	39.7	40.5	40.6	40.1
(°F)	65.0	66.6	72.6	80.3	86.1	90.6	94.6	98.1	101.2	103.4	104.9	105.0	104.2
Hour	13	14	15	16	17	18	19	20	21	22	23	24	--
(°C)	38.4	35.2	31.6	29.1	27.1	25.4	24.1	22.2	21.1	20.1	19.2	18.3	–
(°F)	101.1	95.3	88.8	84.4	80.8	77.8	75.3	72.0	70.0	68.2	66.5	65.0	--

5.5 Calculation of Mass of Hot Soak and Diurnal Emissions

The calculation of the mass of the hot soak and diurnal emissions is as specified in Part III.D.11. of the "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles," as last amended September 2, 2015, except that the actual volume of the test engine or equipment unit as tested shall be used rather than the volume of 50 ft³ specified for a vehicle. The following equation shall be used to calculate ethanol mass:

$$M_{C_2H_5OH} = (V_n - V_{SORE}) \times \left[\frac{(C_{S1f} \times AV_{1f}) + (C_{S2f} \times AV_{2f})}{V_{Ef}} - \frac{(C_{S1i} \times AV_{1i}) + (C_{S2i} \times AV_{2i})}{V_{Ei}}\right] + (M_{C_2H_5OHout} - M_{C_2H_5OHin})$$

where:

V_{SORE} is the volume of the test engine or equipment unit as tested; and the other terms are as defined in section 11.2 of the “California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles,” as last amended September 2, 2015.

6. ~~TEST FUEL~~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 fuel defined in 40 CFR Part 1065.710(b) for general testing.

For engines that are not gasoline-fueled and that are powered with compressed natural gas (CNG), propane, liquefied petroleum gas (LPG), or liquefied natural gas (LNG), testing according to this procedure shall be conducted using a fuel meeting the requirements of section 1065.701 of the “California Exhaust Emission Standards and Test Procedures for New 2013 and Later Small Off-Road Engines; Engine-Testing Procedures (Part 1065),” adopted October 25, 2012, and amended [insert amended date].

~~The fuel specified in part II, section A.100.3.1.1 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, may be used as an alternative test fuel to certify fuel tanks for use on engines and equipment through model year 2019.~~

7. ~~Alternative Test Procedures~~Alternative Test Procedures

Test procedures, other than specified above, such as the use of a mini-SHED to measure diurnal evaporative emissions, 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.

Attachment 1 to TP-902

Procedure for Determining Carbon Canister Performance: Durability Demonstration and Working Capacity

Attachment 1

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Small Off-Road Engine Evaporative Emissions Test Procedure

Attachment 1

Procedure for Determining Carbon Canister Performance: Durability Demonstration and Working Capacity

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 designate.

1 ~~APPLICABILITY~~Applicability

This Test Procedure is used by the California Air Resources Board to determine the performance of carbon canisters used to control evaporative emissions from equipment that use spark-ignited small off-road engines. Small off-road engines are defined in title 13, Cal. Code Regs., 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 small off-road engines 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 an evaporative emission control component, technology, or system by the Executive Officer does not exempt the same 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~~Principle and Summary of Test Procedure

This test procedure is designed to provide consistent methods to evaluate the durability and working capacity of carbon canisters utilized on small off-road engines.

Working capacity is a defining parameter expressing the mass of total organic material hydrocarbon equivalent that can be stored in the canister under controlled conditions. The canister's working capacity is established by repeated canister loading and purging. This procedure involves a cycle that includes a 400 bed volume purge, a 5 minute pause, and then loading the canister with butane mixed 50/50 by volume with air or nitrogen to a measured breakthrough.

3 ~~BIASES AND INTERFERENCES~~Biases and Interferences

To accurately quantify the working capacity the complete test system must be leak tight. Loose fittings and connectors may result in leaks that can significantly affect working capacity determinations.

Care shall be taken to minimize or limit the humidity of the air or nitrogen used to purge the canister. Humid purge air can bias canister desorption weight measurements. Dessicants, or other suitable dehumidification methods, must be used to control the humidity of the purge air.

4 ~~SENSITIVITY AND RANGE~~Sensitivity and Range

For mass measurements greater than 1000 grams, the minimum sensitivity of the balance shall be 0.01 grams. For mass measurements less than or equal to 1000 grams, the minimum sensitivity of the balance shall be 0.001 grams.

5 ~~EQUIPMENT CALIBRATIONS~~Equipment Calibrations

Mass flow meters must undergo an annual multiple point calibration with a primary standard. A plot of the rate measured by the flow meter versus the true flow rate shall have a coefficient of determination, r^2 ~~R^2~~, of 0.99 or greater.

The balance shall be calibrated by an independent organization using ~~National Institute of Standards and Technology (NIST)~~ *Système International d'Unités* (SI)-traceable mass standards annually. The accuracy of the balance shall be checked using ~~NIST~~ SI-traceable mass standards prior to and following mass measurements (25 measurements maximum). At minimum, the accuracy shall be checked at approximately 80~~%~~ percent, 100~~%~~ percent, and 120~~%~~ percent of the canister's expected test mass. If the measured mass of any of the ~~NIST~~ SI-traceable mass standards drifts more than ± 0.02 grams for a balance with 0.01 gram sensitivity or ± 0.002 grams for a balance with 0.001 gram sensitivity between initial and final measurements, the balance shall be re-calibrated or a different balance that is within specification shall be used. The ~~NIST~~ SI-traceable mass standards shall be calibrated annually by an independent organization.

6 ~~CARBON CANISTER WORKING CAPACITY DETERMINATION~~Carbon Canister Working Capacity Determination

6.1 Number of Test Cycles

Working capacity is determined through cyclic loading and purging of a carbon canister. Ten or more cycles may be required to stabilize new carbon. A minimum of three cycles is adequate if the carbon has a previous history of stabilization with butane or gasoline vapors. The “working capacity” value is the lower value of the butane mass supplied to the canister for the last two repeatable cycles.

6.2 Canister Purge

The sequence starts by first purging the canister with 400 bed volumes of dry air or nitrogen in 30 minutes at laboratory conditions. Bed volume is the design volume of the carbon contained in the canister. The purge rate will therefore vary with canister size. Purge may be accomplished by drawing a vacuum at the tank or purge port, or by pushing air or N_2 into the atmospheric vent.

6.3 Pause

Pause testing for approximately 5 minutes between both purge and load and also load and purge sequences.

6.4 Measurement

Weigh the test canister before and after each canister load sequence.

6.5 Canister Load

Load the test canister with butane mixed 50/50 by volume with air or nitrogen until the specified breakthrough criterion has been met. The canister load is accomplished by flowing the butane mixture into the canister via the tank fitting. The butane load rate must be within ± 10 percent of the specified load rate below. The butane load rates and breakthrough criteria are determined by canister’s bed volume. In order to accommodate the expected wide range of canister bed volumes expected in small off-road engines, four ranges of canister loading and breakthrough criteria are defined: small (~~< 99cc~~< 100 cc), medium (~~100 to 249cc~~≥ 100 cc and < 250 cc), large (~~249 to 550cc~~≥ 250 cc and ≤ 550 cc), and extra large (> 550 cc). The load and breakthrough criteria are defined as follows:

Carbon Canister Bed Volume	Small < 99cc≤ 100 cc	Medium 100 to 249cc≥ 100 cc and < 250 cc	Large 249cc to 550≥ 250 cc and ≤ 550 cc	Extra Large > 550 cc
Butane Load Rate [grams C_4H_{10} / hour]	5.0	10.0	15.0	15.0
Breakthrough limit [grams](*)	2.0	2.0	2.0	2.0

(*) If the canister shows mass loss prior to the 2.0 grams breakthrough then an alternate lower breakthrough limit can be used.

7 CALCULATING RESULTSCalculating Results

The following equation shall be used to calculate butane load rate:

$$Q_b = 3{,}600 \times \frac{(m_f - m_i) + m_b}{t}$$

where:

Q_b = butane load rate (grams C_4H_{10} per hour)
3,600 = the number of seconds in one hour
m_f = final carbon canister mass (grams)
m_i = initial carbon canister mass (grams)
m_b = breakthrough mass (grams)
t = duration of load cycle (seconds)

The working capacity is the lower test canister weight gain in grams determined from the last two load cycles. The resultant working capacity is expressed in grams of C_4H_{10}.

8 RECORDING DATARecording Data

Record data on a form similar to the one shown in Figure 1 (see page 8).

9 FIGURESFigures

Figure 1. Canister Data Sheet

Figure 1
Canister Data Sheet

Canister Manufacturer:

Canister I.D:

Tested By:

Canister Volume [cc]:

Canister Purge Data

Time Start/End		Duration t [seconds]	Flow Rate Q [LPM]	Initial Mass m_i [grams]	Final Mass m_f [grams]	Mass Loss m_l [grams]

Canister Load Data

Time Start/End		Duration t [seconds]	Butane Load Rate Q_b [g/hr]	Initial Mass m_i [grams]	Final Mass m_f [grams]	Break-Through m_b [grams]	Mass Gain m_g [grams]
						Working Capacity [grams C_4H_{10}]	