CALIFORNIA AIR RESOURCES BOARD

Small Off-Road Engine Evaporative Emissions Test Procedure

TP-902

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

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California Environmental Protection Agency
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Small Off-Road Engine Evaporative Emissions Test Procedure

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Test Procedure for Determining 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 "ARB" refers to the California Air Resources Board, and the term "Executive Officer" refers to the ARB Executive Officer or his or her authorized representative or designate.

1. APPLICABILITY

This Test Procedure, TP-902, is used by the Air Resources Board to determine the 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

2.1 Durability Demonstration

A durability demonstration shall be performed on the evaporative emission control system of a test engine prior to its diurnal 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 test shall be performed prior to any preconditioning of the fuel tank. 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. 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 $meter \cdot second^{-2}$ 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. 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.

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 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 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.

3. GENERAL SUMMARY OF TEST PROCEDURE

A Sealed Housing for Evaporative Determination (SHED) is used to measure diurnal 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 diurnal emissions from engines or equipment with complete evaporative emission control systems as defined in title 13, Cal. Code Regs., section 2752 (a)(7) 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 °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 24-hour diurnal profile is compared with the diurnal emission standards in title 13, Cal. Code Regs., section 2754. Engines or equipment with emissions below the appropriate diurnal emission standard shall be considered compliant.

4. 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 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 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 §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:

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

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.

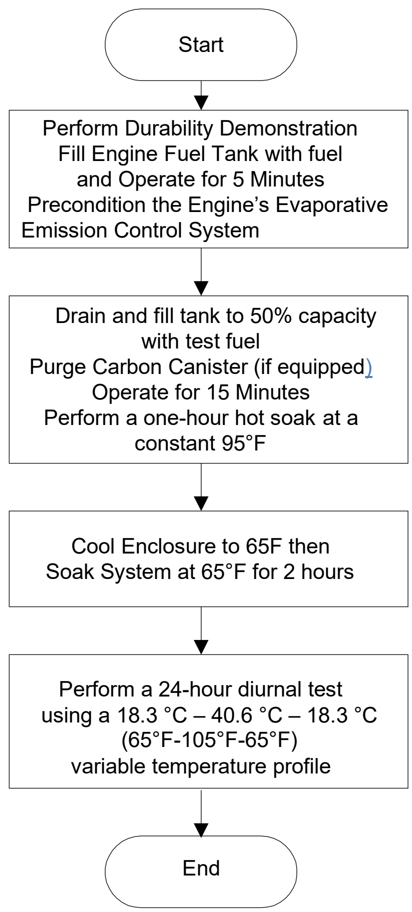
(H) If the calculated final recovered HC mass for the enclosures is not within 3 percent of the initial enclosure mass, or if the calculated final recovered ethanol mass for the enclosures is not within 6 percent of the initial enclosure mass, then action shall be required to correct the error to the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

5. TEST 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. As an alternative, accelerated preconditioning of the evaporative emission control system can be accomplished by soaking at an elevated temperature. Data documenting that the diurnal emissions will not increase with further preconditioning must be provided for tanks soaked less than 140 days. 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.

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. For evaporative emission control systems that use a carbon canister, the canister must be purged following the preconditioning period but prior to initiating the hot soak test. Purging consists of drawing 400 bed volumes of nitrogen or dry air through the canister at the canister manufacturer's recommended purge rate. Operate the engine at its maximum governed speed for fifteen minutes. Immediately place the engine in the SHED enclosure preheated to 35 °C. Perform a one-hour hot soak at a constant 35 °C.

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.

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 ft^3 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

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.

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

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 ARB Executive Officer. In order to secure the ARB Executive Officer's approval of an alternative test procedure, the applicant is responsible for demonstrating to the ARB 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 "ARB" refers to the California Air Resources Board, and the term "Executive Officer" refers to the ARB Executive Officer, or his or her authorized representative or designate.

1 APPLICABILITY

This Test Procedure is used by the 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

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

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

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

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, of 0.99 or greater.

The balance shall be calibrated by an independent organization using National Institute of Standards and Technology (NIST)-traceable mass standards annually. The accuracy of the balance shall be checked using NIST-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-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-traceable mass standards shall be calibrated annually by an independent organization.

6 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 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), medium (100 to 249cc) large (249 to 550cc) and extra large (> 550cc). The load and breakthrough criteria are defined as follows:

Carbon Canister Bed Volume	Small < 99cc	Medium 100 to 249cc	Large 249cc to 550	Extra Large >550
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 RESULTS

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 DATA

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

9 FIGURES

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 [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 [seconds]	Butane 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}]	