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SURFACE VEHICLE RECOMMENDED PRACTICE

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MEASUREMENT OF FUEL EVAPORATIVE EMISSIONS FROM GASOLINE POWERED PASSENGER CARS AND LIGHT TRUCKS USING THE ENCLOSURE TECHNIQUE

(R) ***1. Scope***—This SAE Recommended Practice describes a procedure for measuring evaporative emissions from fuel systems of passenger cars and light trucks. Emissions are measured during a sequence of laboratory tests that simulate typical vehicle usage in a metropolitan area during summer months:

a. A 1 h soak representing one diurnal cycle in which temperature of fuel in the vehicle's tank is raised from 15.6 to 28.9 °C (60 to 84 °F)
b. A 17.9 km (11.1 mile) drive on a chassis dynamometer
c. A 1 h hot soak immediately following the 17.9 km (11.1 mile) drive

(R) The method described in this document, commonly known as the SHED (Sealed Housing for Evaporative Determination) technique, employs an enclosure in which the vehicle is placed during the diurnal and hot soak phases of the test. Vapors that escape from all openings in the fuel system—both expected and unexpected—are retained in the enclosure, and the increase in hydrocarbon (HC) concentration of the atmosphere in the enclosure represents the evaporative emissions. Emission values measured by the enclosure method can, therefore, be significantly different than those obtained by the former trap method, depending on fuel system configuration and component design.

The test sequence and methods for measuring emissions are applicable to vehicles either with or without systems or devices to control fuel evaporative emissions. Although they have been used successfully with a wide range of vehicles equipped with a variety of control devices, they should not be applied indiscriminately to new or unique vehicles or fuel systems. For example, based on experience that temperature excursions of the fuel tank in parked vehicles follow those of ambient air, the test sequence prescribes heating of the fuel tank to simulate a diurnal soak. Any control system designed to alter the relation between fuel and ambient temperatures will not be properly evaluated in the test sequences prescribed.

This document is intended as a guide toward standard practices, but may be subject to frequent change to keep pace with experience and technical advances.

The document includes the following sections:

a. Definitions
b. Test Fuel
c. Test Facilities and Equipment
d. Measurement Method
e. Preparation of Test Vehicle and Fuel System
f. Test Sequence

g. Information and Data to be Recorded
h. Presentation of Data

2. References

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

SAE J1094—Constant Volume Sampler System for Exhaust Emissions Measurement

Jacobs, Anal Chem, Volume 28 March 1956

Jackson, M. W., Journal of the Air Pollution Control Association Vol 16, December, 1966, p. 697, "Analysis of Exhaust Gas Hydrocarbons—NDIR vs. Flame Ionization"

2.2 Definitions—The following definitions apply to the terms used:

2.2.1 LOADED VEHICLE WEIGHT—Loaded vehicle weight is the manufacturer's estimated weight of the vehicle in operating condition with all standard equipment, the weight of fuel at nominal tank capacity, the weight of every item of optional equipment which weighs over 1.4 kg (3 lb) and which is installed on more than 33% of an engine displacement class, plus 136 kg (300 lb).

2.2.2 EVAPORATIVE EMISSIONS—Evaporative emissions are fuel vapors emitted into the atmosphere from the vehicle.

2.2.3 FUEL SYSTEM—Fuel system means the combination of fuel tank, fuel lines, pump, filter, and vapor return lines, carburetor or injection components, and all fuel system vents and evaporative emission control systems or devices.

2.2.4 SYSTEM OR DEVICE—System or device includes any vehicle modifications that control or reduce the amount of fuel vapors emitted from the vehicle.

2.2.5 CONTROLLED VEHICLE—Controlled vehicle means a vehicle equipped with systems or devices to reduce the amount of evaporative emissions.

2.2.6 HOT SOAK LOSSES—Hot soak losses are fuel vapors emitted during a specified period beginning immediately after the engine is turned off.

2.2.7 DIURNAL BREATHING LOSSES—Diurnal breathing losses are fuel vapors emitted as a result of a specified increase in fuel tank temperature in a specified time.

2.2.8 RUNNING LOSSES—Running losses are fuel vapors emitted during operation of the vehicle under the specified test schedule.

2.2.9 TANK FUEL VOLUME—Tank fuel volume is 40% of nominal tank capacity, rounded to the nearest whole U. S. gallon (multiple of 3.8 L).

3. Test Fuel—Although any fuel can be used for the test sequence described, the effectiveness of evaporative emission control systems is usually evaluated with a test fuel representative of that commercially available, or expected to be commercially available, during the summer months. If the purpose of the test is to determine the effects of changes in fuel volatility on evaporative emissions, use of noncommercial fuels may be necessary.

3.1 Test Fuel Identification—To properly identify the fuel used, it should be inspected for the properties shown in Table 1.

A determination of nonreflux batch distillation temperatures may help in understanding the mechanism of carburetor hot soak losses and determination of true vapor pressure may help in understanding the mechanism of fuel tank losses. However, neither of these tests has been standardized by ASTM.

TABLE 1—MEASUREMENT OF FUEL PROPERTIES

Property	ASTM Test Method
Distillation	D 86
IBP	—
5% Evaporated	—
10%	—
15%	—
20%	—
30%	—
40%	—
50%	—
90%	—
FBP	—
Reid vapor pressure, psi	D 323
Hydrogen-carbon ratio[1]	D 1018

[1] The hydrogen-carbon (H/C) ratio is required for the final calculation of evaporative losses using the enclosure method. The H/C ratio of condensed evaporative emissions will differ from that of the test fuel. If extremely accurate estimates of the amount of emissions are desired, the H/C ratio should be determined separately for condensed diurnal (fuel tank) and hot soak (carburetor) emissions. If routine laboratory accuracy is acceptable (±5%), a single H/C ratio of the IBP to 54 °C (130 °F) distillation cut of the fuel can be used for all calculations of emissions by the enclosure method. H/C ratio can alternatively be measured by β-ray absorption, which is quick and accurate (see Jacobs, et al., Anal Chem., Vol. 28, March 1956).

3.2 Fuel Sampling—A sample of test fuel for laboratory inspection should be taken from the fuel source at the start of the test. A 0.5 L (1 pt) container, precooled to 4 °C (40 °F) or less, should be used. It should be bottom filled to overflow and then poured out to 80% capacity. The container should be tightly sealed immediately after filling and stored at 4 °C (40 °F) or less until fuel inspection tests are made. Alternate sampling procedures may be substituted, but care must be exercised with any sampling procedure to prevent the loss of volatile constituents from the fuel during either sampling or storage.

4. Test Facilities and Equipment—Provisions must be made for controlling the environment of the vehicle, absorbing power, fueling and cooling the vehicle, and heating the fuel tank.

4.1 Environment—Appropriate controls should be provided to maintain temperature between 20 and 30 °C (68 and 86 °F) for the preconditioning soak and evaporative emission tests.

4.2 Power Absorption—A chassis dynamometer with power absorption and inertia loading capabilities is required. The dynamometer's power and inertia capacities must be adjustable to adsorb road load power at 80.5 km/h (50 mph) and simulate proper vehicle inertia during acceleration.

4.3 Vehicle Cooling—A fixed-speed fan is needed to maintain engine cooling and to provide proper fuel tank heating when the vehicle is running on the chassis dynamometer. The fan capacity must be between 142 and 159 m^3/min (5000 and 5600 ft^3/min). Additional cooling may be used if necessary to simulate road conditions.

4.4 Tank Fuel Heating—An electric heating pad is needed to heat tank fuel during the diurnal soak. This pad should cover 50% or more of the area wetted by the test fuel. A 2000 W heating pad with a variable voltage transformer to regulate heat output should be adequate in most vehicles. Alternative heating methods may be used on vehicles of unusual configuration or if necessary to comply with local laboratory practices. All methods should avoid hot spots in the tank wetted surface which could cause local overheating of the fuel. Heat must not be applied to the vapor in the tank above the liquid fuel. With proper heating of the tank, vapor temperature will not exceed liquid temperature by more than 3.3 °C (6 °F) at completion of the diurnal soak. Thermocouples and a multichannel, potentiometric-type recorder with 0.5 °C (1 °F) accuracy and with variable chart speed should be used for monitoring temperatures.

4.5 Fueling—Facilities and safeguards must be provided for draining and refilling vehicle fuel tanks. The work area must be well ventilated. Drain and filling connectors and containers must be grounded to the vehicle tank. If tanks have a suitable drain fitting, they may be drained by gravity. If not, they may be pumped dry through the fill pipes. Many tanks are difficult to drain either way, and care should be taken to insure that the tanks are adequately drained. During fuel drain, assure that evaporative control system is not abnormally purged. Facilities must be provided to refill vehicle tanks to the specified tank fuel volume with fuel at a temperature such that, at completion of the fill, the fuel temperature in the tank is above 10 °C (50 °F) and at or below 14.4 °C (58 °F). Test fuel in storage may require special temperature control to comply with this temperature limit. Drained fuel cannot be reused for emission tests.

(R) ***5. Measurement Method***—The car enclosure method provides for sealing the vehicle in an enclosure during the soak phases of the test. Evaporative emissions are determined from the changes in the hydrocarbon concentrations in the enclosure. This method produces a single measurement of evaporative emissions during a soak, regardless of the number of sources. It can be used to measure evaporative emissions without modifications to the vehicle. It is not applicable to the run phase.

5.1 Equipment Requirements—An enclosure with internal dimensions of 3 × 6 × 2.6 m (10 × 20 × 8.5 ft) high will accommodate vehicles with up to 330 cm (130 in) wheelbase, and has been found convenient for testing most U. S. passenger cars. The foregoing dimensions may be adjusted to accommodate different size vehicles without significantly affecting the test results. The enclosure door must allow entry of the maximum size vehicle. Door sealing may be accomplished by a resilient gasket, an inflatable seal, or a pressure sealing zipper if a flexible door is used.

Interior surfaces must be impermeable to hydrocarbon. Permeable materials may be covered with polyvinyl fluoride[1] sheet of approximately 0.15 mm (0.006 in) thickness. One wall, or door or ceiling, should be of flexible material such as 0.15 mm (0.006 in) polyvinyl fluoride sheet to provide a safety "blow-out" panel, and to allow for minor temperature changes of the contained gas without excessive "breathing."

Walls are a barrier to dissipation of heat and should consequently be of minimum thermal resistance. During the hot soak sequence, the temperature of the enclosure atmosphere rises above external room temperature. Some provision may be necessary for limiting temperature to 30 °C (86 °F) or less. Directing the discharge from an internal blower against an enclosure wall may help to control peak temperature. No portion of the airstream shall be directed toward the vehicle. The maintenance of uniform concentrations throughout the enclosure is important to the accuracy of the test. Additional temperature control can be realized by application of airstreams to the outside surfaces of the enclosure walls, but this must be done carefully because high velocity may aggravate leaks. The enclosure cooling system must be controlled so that no interior surface temperature falls below 20 °C (68 °F). Photographs of two enclosures that have been used successfully are shown in Figure 1.

The enclosure must be equipped with a flame ionization detector (FID) hydrocarbon analyzer[2] capable of measuring hydrocarbon concentrations reliably in the range of 10 to 3000 ppm carbon.

[1] "Tedlar" or equivalent.
[2] A general description of HC analyzers is given in the Journal of the Air Pollution Control Association, Vol. 16, December, 1966, p. 697, "Analysis of Exhaust Gas Hydrocarbons—NDIR vs. Flame Ionization," by M. W. Jackson.

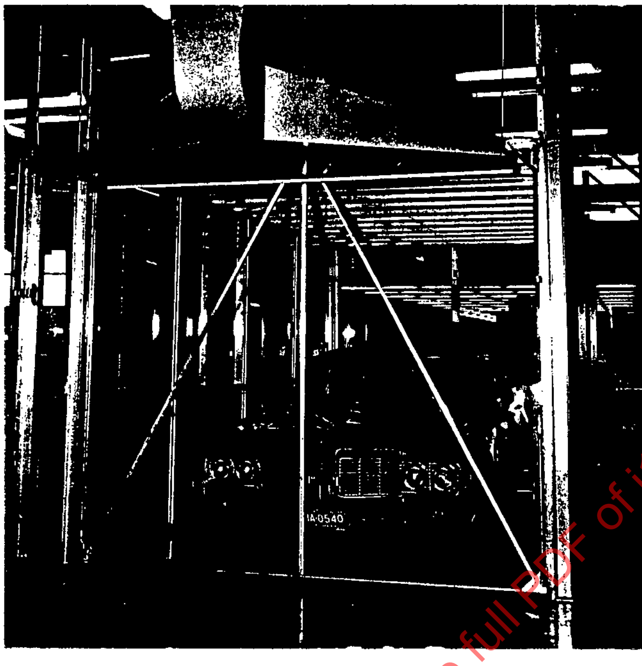

FIGURE 1—CAR ENCLOSURE

Fuel gases recommended by the manufacturer of the FID and calibrating gases are required as follows:

a. Ultrapure grade zero air
b. 50 ppm propane in air (nominal)
c. 100 ppm propane in air (nominal)
d. 300 ppm propane in air (nominal)
e. 1000 ppm propane in air (nominal)

A typical sample train for the analyzer is shown in Figure 2. The sample should be withdrawn from the enclosure through a tube of 6.4 mm (1/4 in) ID, terminating 50.8 to 305 mm (2 to 12 in) inside the wall and located on the geometric center of the wall opposite the door or on one of the sides or below the center of the ceiling. The tubing connecting this tube to the analyzer should be of 6.4 mm (1/4 in) OD stainless steel or similar inert material and should be as short as possible.

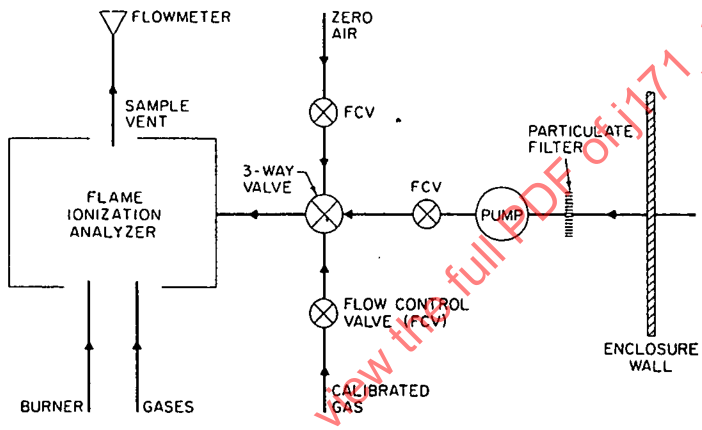

FIGURE 2—FID SAMPLE TRAIN

A blower (portable or fixed) of 42.5 to 158.6 m^3/min (1500 to 5600 ft^3/min) capacity is required for purging the enclosure between tests, and one or more explosion-resistant blowers of 2.8 to 28 m^3/min (100 to 1000 ft^3/min) total capacity is required for mixing the enclosure atmosphere during tests. Two thermocouples for monitoring the enclosure temperature should be installed 76 cm (30 in) above the floor and 10 cm (4 in) in from either side, both midway along the length of the enclosure.

5.1.1 SYSTEM CHECKOUT—The complete enclosure measurement system should be checked initially and periodically for calibration, hydrocarbon retention (leakage) and self emission. Appendix A gives details.

5.2 Operating Sequence for Vehicle Soak in Enclosure

5.2.1 Zero and calibrate gas analyzer.

5.2.2 With door open, discharge purge blower into enclosure for several minutes immediately prior to test.

5.2.3 Push or coast the vehicle with engine off into the enclosure and make thermocouple connections. For diurnal test, position gasoline tank heating blanket. Open all windows and luggage compartments.

5.2.4 Start mixing blower and orient it such that it does not discharge directly against the vehicle.

5.2.5 Close and seal door. Obtain a stable initial reading of FID analyzer. Read enclosure interior air temperature and barometric pressure.

5.2.6 Read enclosure hydrocarbon concentration, enclosure interior air temperature and vehicle test instrumentation at 5 min intervals throughout soak test. Abort any test if the hydrocarbon concentration exceeds 15 000 ppm carbon, and immediately vent the enclosure. This concentration provides a 4:1 safety factor against the lean flammability limit.

5.2.7 Read hydrocarbon concentration at the end of the soak and subtract initial from final reading to determine the net concentration of hydrocarbon. Check the analyzer zero and calibration points to insure that they have not drifted.

5.3 Calculation of Emissions—The mass of emissions is calculated from the net hydrocarbon concentration of the enclosure in ppm carbon, enclosure volume, temperature and pressure, using the following equation:

$$M_{HC} = \frac{kC_{HC}VP \times 10^{-4}}{T} \quad \text{(Eq.1)}$$

where:

- M_{HC} = HC mass, g
- C_{HC} = net hydrocarbon concentration as ppm carbon
- V = enclosure volume, m^3 (ft^3) (subtract car volume for vehicle tests, approximately 1.42 m^3 (50 ft^3) with windows and trunk open)
- P = barometric pressure, kPa (in Hg), measured when door is closed and sealed
- T = enclosure ambient temperature K (°R), measured when door is closed and sealed
- H/C = atomic hydrogen to carbon ratio of evaporative emissions
- k = 0.208 (12 + H/C) = 2.97 for average evaporative emissions

(In SI units, k = 1.20 (12 + H/C) = 17.1)

Note that hydrocarbon concentration is stated in ppm carbon, that is, ppm propane × 3. Derivation of this equation is shown in Appendix B.

5.4 Car Background Emissions—Vehicles contain many sources of nonfuel hydrocarbon emissions. Experience shows these emissions to be relatively small for vehicles more than 60 days old that are in good repair. However, the "background" emissions should be measured and subtracted from the values observed during the soak sequences. Appendix C details procedures for measurement of car background emissions.

6. Preparation of Test Vehicle and Fuel System—Some suggestions on vehicle preparation follow, but it may be necessary to expand or modify them for individual cases.

6.1 Instrumentation—Tank fuel temperature must be monitored continuously during the diurnal breathing loss test. A thermocouple to read tank fuel temperature must be located near the geometric center of the tank fuel liquid. Additional thermocouples, fuel system pressure taps, etc., may be installed on the test vehicle provided they do not affect the operation of the vehicle or function of the evaporative control system.

6.2 Visual Inspection—After instruments have been installed, the engine should be started and run for approximately 5 min. The vehicle should be inspected for liquid fuel or oil leaks while the engine is running. Leaks must be repaired and all traces of fuel spillage removed. Special care should be exercised to eliminate any leaks in the windshield washer system. Washer solvents usually contain an alcohol that will be detected by the hydrocarbon analyzer and recorded as a fuel evaporative loss.

6.3 Fuel System Pressure Test—A pressure test of the fuel tank assembly, filler cap, filler pipe, fuel lines, fuel vapor lines, and other components should be made to insure the integrity of the fuel system and to check performance of any pressure control device(s) of the evaporative control system.

A pressure test is not absolutely necessary with the enclosure method, but it does serve to detect fuel leaks that would affect magnitude of the fuel emissions observed.

Dry nitrogen is preferred for pressure testing, but air can be used. Pressures must not significantly exceed the maximum designed operating pressures of the fuel system. Usually, a loss of pressure of less than 10% of the initial stabilized system pressure in 30 min is adequate evidence of fuel system integrity.

No pressure test should be made if it might adversely affect the subsequent performance of the evaporative control system. If the evaporative control system employs a vapor-storage device, the pressure test must not either purge or load the device.

6.4 Car Background Emissions—Determine car background emissions per Appendix C.

6.5 Loading Evaporative Control Systems—If a vehicle is equipped with an evaporative emission control system, before any tests are made the control system must be properly "loaded" by operating the vehicle until the amount of hydrocarbon retained in the control system is at equilibrium. Surveys of driving practices have indicated that typical vehicle use in a metropolitan area consists of three to four trips per day, and of course, three or four hot soaks and one diurnal soak daily.

Some vapor storage devices—such as charcoal absorbers—have the capacity to retain more vapors (as might be emitted during diurnal or hot soak phases) than can be purged during a single 12.1 km (7.5 mile) trip. Systems using these devices are called "accumulative." Present experience indicates that systems using the engine crankcase as an absorber are not accumulative; usually, this system will purge all stored vapors in one trip. However, in either system, but especially in an accumulative system, vapor loading too high at the start of a test could result in unrealistically high emissions. With an accumulative system, vapor loading too low at the start of a test could result in unrealistically low emissions. Several criteria can be used to judge whether the control system is properly loaded. Which one should be used depends upon the type of control system and the test objectives.

If the test objectives are to measure evaporative emissions in a sequence representing one diurnal soak, one trip, and a 1 h hot soak in which the control system is to be purged of all vapor generated by the diurnal and hot soak phases (that is, purge grams > stored diurnal grams + stored hot soak grams), proper loading of the control system would be obtained by these steps:

6.5.1 For an accumulative system in which the vapor storage device can be weighed:

a. Weigh the vapor storage device.
b. Drain and refill the fuel tank.
c. Perform a diurnal soak.
d. Push vehicle onto the chassis dynamometer and run the dynamometer test equivalent to the trip. The engine must be shut down within 5 min after the end of the test.
e. Perform a 1 h hot soak.
f. Weigh the vapor storage device.
g. Repeat steps b through f until the weight of the device is constant within 5 g.

6.5.2 For a nonaccumulative system:

a. Drain and refill the fuel tank.
b. Perform a diurnal soak.
c. Push vehicle onto the chassis dynamometer and run the dynamometer test. The engine must be shut down within 5 min after the end of the test.
d. Perform a 1 h hot soak.

6.5.3 If the test objectives are to measure evaporative emissions in a test sequence representing one diurnal soak, three trips, and a hot soak following each trip in which the control system is to be purged of all vapor generated during the diurnal and hot soaks (that is, purge grams per trip =

(stored diurnal grams/3) + stored grams per hot soak), proper loading of accumulative control system which can be weighed would be obtained by these steps:

a. Weigh the vapor storage device.
b. Drain and refill the fuel tank.
c. Perform a diurnal soak.
d. Reweigh the vapor storage device to determine the increase in fuel vapor content (stored grams).
e. Push vehicle onto the chassis dynamometer and run the dynamometer test. The engine must be shut down within 5 min after the end of the test.
f. Weigh the vapor storage device to determine its loss in fuel vapor content (purged grams). Making this measurement interrupts the test sequence, but should not affect test results if it is done quickly (within 1 or 2 min).
g. Perform a 1 h hot soak.
h. Weigh the vapor storage device to determine the increase in fuel vapor content (stored grams).
i. Repeat these steps, individually and/or in sequence, until it is evident that the purged grams from one dynamometer test run equals or exceeds one-third of the stored diurnal grams and all of the stored hot soak grams.

It is permissible to artificially load the vapor storage device with fuel vapors to shorten the number of tests needed to obtain equilibrium loading of the device.

7. ***Test Sequences***—The test sequence consists of three phases intended to simulate typical vehicle usage in a metropolitan area during the summer months:

a. A 1 h diurnal soak during which time the tank fuel is heated from 15.6 to 28.9 °C (60 to 84 °F).
b. A 17.9 km (11.1 mile) run (approximate) conducted on a chassis dynamometer from a "cold" start.
c. A 1 h hot soak immediately following the 17.9 km (11.1 mile) run.

Evaporative emissions from the vehicle fuel system are measured during each of the three phases. However, measurements during the run phase on a vehicle with an evaporative control system may be omitted if it is apparent that by system design, all "running losses" will be inducted into the engine. If "running loss" measurements are required, the trap method or some other method must be used to measure emissions during the run phase.

7.1 Vehicle Temperature Stabilization—Before the test, the vehicle must be soaked (engine off) for a minimum of 11 h at an ambient temperature of 20 to 30 °C (68 to 86 °F) so that all parts stabilize at the prescribed temperature. A maximum soak time may be imposed by the test procedure for an associated exhaust emission test. The vehicle preconditioning and the remaining steps described in this section must be performed in sequence and without interruption. This soak should be limited to not more than 16 h unless the ambient temperature increases beyond that time can be held to less than 2.2 °C (4 °F). It is assumed that no significant vapor loading of a storage system, due to tank breathing, occurs during this soak (after the initial hot soak following any required preconditioning run).

7.2 Tank Refueling—The fuel tank must be drained and refilled to the tank fuel volume with fresh test fuel. After refueling, temperature of the fuel in the tank must be above 10 °C (50 °F) and at or below 14.4 °C (58 °F).

7.3 Soak and Running Phases

7.3.1 DIURNAL BREATHING LOSS—Following tank refueling, push vehicle into the enclosure. Heat fuel to 14.4 °C (58 °F), install fuel cap(s), close and seal enclosure door, continue heating fuel to 15.6 °C ± 1 (60 °F ± 2). Make initial reading on FID. Read temperature and barometric pressure. Heat the tank fuel 13.3 °C ± 0.5 (24 °F ± 1) at a constant rate during a period of 60 min ± 2. For vehicles with multiple tanks, the largest tank shall be designated as the primary tank and shall be heated in accordance with the procedures described in this section. All other tanks shall be designated as auxiliary tanks and shall undergo a similar heat build such that their fuel temperature shall be within 1.6 °C (3 °F) of the primary tank. The enclosure interior air temperature should be monitored and held between 20 and 30 °C (68 and 86 °F).

7.3.2 Preparation for Running—At the end of the 1 h soak, record final enclosure hydrocarbon concentration and auxiliary information required to calculate emissions.

If required, connect traps to measure "running losses" from tank vents or other fuel system vents.

7.3.3 Running Loss—Push test vehicle onto the chassis dynamometer. Time between the end of the diurnal soak and starting the engine for this phase should not exceed 60 min. Run according to dynamometer test as described in Appendix D.

Immediately after completion of the dynamometer test, shut off the cooling fan, but allow the engine to continue running at idle while the instruments and/or test equipment connections are disengaged from the vehicle. After enclosure is purged, drive the vehicle off the dynamometer and push or coast vehicle with engine off into the enclosure. Time from completion of the dynamometer test until engine shutdown must not exceed 5 min.

7.3.4 Hot Soak Phase—Turn off the enclosure purge blower and seal the enclosure door within 2 min after engine shutdown.

Soak vehicle in the enclosure with the hood down and windows and luggage compartments open for 60 min ± 0.5. Enclosure interior air temperature during the final 55 min should be held between 20 and 30 °C (68 and 86 °F). Perform necessary measurements and calculations as described for the diurnal soak phase.

8. Information and Data to be Recorded—Details are listed on the sample data sheet (Figures E1, E2, and E3) in Appendix E.

8.1 Information

a. Test identification
b. Tests performed and description
c. Vehicle description
d. Engine description
e. Fuel system description

8.2 Data to be Collected

a. Temperatures
b. Barometric pressure
c. Hydrocarbon concentrations at specified sampling times
d. Car enclosure method records

9. Presentation of Data

a. Objective of test
b. Description of system under test
c. Conclusion from the test
d. Discussion of the test and the system
e. Test tabulation or plots

10. Notes

10.1 Marginal Indicia—The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

PREPARED BY THE SAE EXHAUST EMISSIONS STANDARDS COMMITTEE

APPENDIX A

CAR ENCLOSURE SYSTEM CHECKOUT

A.1 ***Calibration***—Zero and calibrate gas analyzer. After discharging purge blower into enclosure for several minutes, seal door and read enclosure background hydrocarbon (HC) concentration.

Inject approximately 4 g of light hydrocarbon material (for example, propane) into the enclosure. (This can be conveniently accomplished with a valved probe through an enclosure wall similar to the sample probe described in 5.1. A small pressure vessel containing the propane should be weighed before and after discharge into the enclosure through the probe.)

After 5 min of mixing blower operation, read the stabilized enclosure hydrocarbon concentration. Subtract the enclosure background and use the net concentration to calculate the mass of HC contained in the enclosure.

Discrepancy between the calculated hydrocarbon mass and the injected hydrocarbon mass should be less than 2% for a satisfactory calibration.

A.2 ***Hydrocarbon Retention (Leak Check)***—Inject approximately 4 g of light hydrocarbon material into the enclosure as specified in the "calibration" procedure above. Record enclosure hydrocarbon concentration.

Allow the enclosure to remain sealed for 4 h without sampling interior gases. The mixing blower should continue to operate throughout this period.

Read final hydrocarbon concentration. The difference between initial and final concentrations should indicate less than 4% mass "leakage."

A.3 ***Emission Check***—It should be demonstrated that a new enclosure structure does not contain materials which will themselves emit hydrocarbon.

Seal the enclosure after thoroughly purging. Read hydrocarbon concentration at the beginning and end of a 4 h period without sampling during the interim. Change in hydrocarbon concentration should be negligible, but in any case should be less than 0.1 g/h (mass equivalent) to be considered acceptable.

APPENDIX B

DERIVATION OF EQUATION FOR ENCLOSURE GIVING M_{HC} AS A FUNCTION OF C_{HC}

B.1 Assume that the enclosure is gas tight and sealed at or before the time of initial reading. Also assume one enclosure surface is of flexible, impermeable material to assure that the internal enclosure pressure is substantially the same as the ambient pressure. Also assume that the geometric volume (V) of air contained in the enclosure has been measured and is the enclosure volume at the time of the initial reading.

The hydrocarbon mass change during the test (M_{HC}) is given by:

$$M_{HC} = W(n_f - n_i) \quad \text{(Eq.B1)}$$

where:

W is the molecular weight of the hydrocarbon and n is the number of moles of gaseous hydrocarbon in the enclosure. If we assume that both air and the hydrocarbon (at its low partial pressure) behave as ideal gases,

$$n_i = \frac{P_{Bi}\underline{V}_i}{RT_i} \quad \text{(Eq.B2)}$$

and

$$C_{HCi} = \frac{\underline{V}_i N(10^6)}{V} \quad \text{(Eq.B3)}$$

or

$$\underline{V}_i = \frac{C_{HCi}V(10^{-6})}{N} \quad \text{(Eq.B4)}$$

where:

$\underline{V}_i$ is the initial partial volume of the hydrocarbon and N is the number of atoms of carbon in the hydrocarbon molecule. V is the enclosure volume, R is the gas constant, P_B is the barometric pressure, T is the enclosure gas temperature, M_{HC} is the hydrocarbon mass, C_{HC} is the HC concentration as ppm carbon, the subscripts f and i represent final and initial readings.

Substituting (Eq.B4) into equation (Eq.B2)

$$n_i = \frac{VC_{HCi}P_{Bi}(10^{-6})}{RNT_i} \quad \text{(EqB5)}$$

Similarly:

$$n_f = \frac{P_{Bf}\underline{V}_f}{RT_f} \quad \text{(Eq.B6)}$$

$$C_{HCf} = \frac{\underline{V}_f N(10^6)}{V_F} \quad \text{(Eq.B7)}$$

$$\underline{V}_f = \frac{C_{HCf}V_F(10^{-6})}{N} \quad \text{(Eq.B8)}$$

where:

V_F is the enclosure volume at the time of final reading. V_F may be different from V because of movement of the flexible enclosure surface in response to pressure changes caused by barometric changes, temperature changes, or an increased concentration of gaseous hydrocarbon.

$$V_F = V \frac{T_f P_{Bi}}{T_i P_{Bf}} \left[1 + \frac{(C_{HCf} - C_{HCi})(10^{-6})}{N} \right] \quad \text{(Eq.B9)}$$

The second term in the bracket is usually negligible compared to 1 and will be neglected (an increase of 3000 ppm carbon as propane will cause a 0.1% error).

Substituting (Eq.B9) into equation (Eq.B8):

$$\underline{V}_f = \frac{C_{HCf} V T_f P_{Bi} (10^{-6})}{N T_i P_{Bf}} \quad \text{(Eq.B10)}$$

Substituting (Eq.B10) into equation (Eq.B6):

$$n_f = \frac{V C_{HCf} P_{Bi} (10^{-6})}{R N T_i} \quad \text{(Eq.B11)}$$

Substituting equations (Eq.B11) and (Eq.B5) into equation (Eq.B1):

$$M_{HC} = \frac{WV(10^{-6})}{RN} \left(\frac{C_{HCf} P_{Bi}}{T_i} - \frac{C_{HCi} P_{Bi}}{T_i} \right) \quad \text{(Eq.B12)}$$

Simplifying,

$$M_{HC} = \frac{0.01WV(10^{-4})}{RN} \; \frac{P_{Bi}(C_{HCf} - C_{HCi})}{T_i} \quad \text{(Eq.B13)}$$

The final result is:

$$M_{HC} = \frac{kV10^{-4} P_{Bi}(C_{HCf} - C_{HCi})}{T_i} \quad \text{(Eq.B14)}$$

where:

$$k = \frac{0.01W}{RN} \quad \text{(Eq.B15)}$$

$$R = \frac{0.04816 \text{ ft}^3 \cdot \text{in Hg}}{\text{mole} \cdot {}^\circ\text{R}} = \frac{8.3143 \times 10^{-3} \text{ m}^3 \cdot \text{kPa}}{\text{mole} \cdot \text{K}} \quad \text{(Eq.B16)}$$

For enclosure volume and leakage checks, the hydrocarbon is propane:

$$W = 44.10 \text{ g/mole} \quad \text{(Eq.B17)}$$

$$N = 3 \quad \text{(Eq.B18)}$$

$$k = 3.05 \frac{\text{g} \cdot {}^\circ\text{R}}{\text{ft}^3 \cdot \text{in Hg}} = 17.68 \frac{\text{g} \cdot \text{K}}{\text{m}^3 \cdot \text{kPa}} \quad \text{(Eq.B19)}$$

For evaporative emission measurement:

$$W = (12 + H/C) \text{ g/mole} \quad \text{(Eq.B20)}$$

$$N = 1 \quad \text{(Eq.B21)}$$

$$k = 0.208(12 + H/C) \frac{\text{g} \cdot {}^\circ\text{R}}{\text{ft}^3 \cdot \text{in Hg}} = 1.20(12 + H/C) \frac{\text{g} \cdot \text{K}}{\text{m}^3 \cdot \text{kPa}} \quad \text{(Eq.B22)}$$

where:

H/C is the hydrogen-carbon ratio.

Hydrocarbon analyses of vehicle evaporative emissions have shown H/C to be 2.2 for hot soak carburetor evaporative losses and 2.33 for diurnal fuel tank evaporative losses. Hence, the corresponding k values for use in (Eq.B14) are:

For Hot Soak:

$$k = 2.95 \frac{g \cdot °R}{ft^3 \cdot in\ Hg} = 17.0 \frac{g \cdot K}{m^3 \cdot kPa} \quad \text{(Eq.B23)}$$

For Diurnal:

$$k = 2.98 \frac{g \cdot °R}{ft^3 \cdot in\ Hg} = 17.2 \frac{g \cdot K}{m^3 \cdot kPa} \quad \text{(Eq.B24)}$$

APPENDIX C

MEASUREMENT PROCEDURE FOR CAR BACKGROUND HYDROCARBON EMISSION

If the car background emission rates, as measured by the following procedures, exceed 1 g/h, repeat tests should be made to establish their consistency before proceeding with emission tests. It should be pointed out that a given sequence of evaporative emission tests should require car background measurements only once.

C.1 Vehicle Preparation

a. Special cleaning operations need not be performed to remove dirt and grease, except when leakages or accumulation are obviously excessive.
b. Remove fuel tank and carburetor.
c. Purge fuel lines and fuel pump with air and plug entrances and exits.
d. Plug all other exits from the engine and exhaust system which could supply a source of hydrocarbon: intake manifold, tailpipe outlet, muffler drain holes, crankcase filler and dipstick openings, PCV, etc.

C.2 "Cold Car Background" Test—(To be used as a subtractive correction to diurnal soak emission measurement.)

Repeat sequence described in 5.2.

C.3 "Hot Car Background" Test—(To be used as a subtractive correction to hot soak emission measurement.)

Reinstall the carburetor on the test car and connect to the external fuel supply. Unplug tailpipe outlet and other atmospheric openings required for engine operation.

Operate car through chassis dynamometer test per Appendix D.

Quickly remove carburetor, being careful not to spill liquid fuel. Reseal intake manifold openings, tailpipe outlet, etc.

Push car to enclosure and repeat test sequence of 5.2.

(R) APPENDIX D

CHASSIS DYNAMOMETER TEST PROCEDURE

The vehicle must be nearly level when tested to insure normal fuel distribution. Drive wheel tires should be inflated to the greater of either 276 kPa (45 psi) gage pressure or the manufacturer's recommended tire pressure to prevent tire damage.

Except for air cooled engines, the cooling fan should be positioned between 20 and 30 cm (8 and 12 in) from the grill and directed squarely at the radiator. Air-cooled engines may require special positioning of the fan contingent on vehicle configuration. In all cases, the running phase is to be conducted with the hood up. Inertia may be obtained by flywheels or may be simulated electrically or by other means. Equivalent inertia weight and absorbed power should be adjusted according to the table in the latest version of SAE J1094.

If the equivalent inertia specified is not available on the dynamometer being used, the next higher value (but not more than 114 kg (250 lb) higher) should be used. The dynamometer should be adjusted for the specified power absorption at 80.5 km/h (50 mph) and the setting of the power absorption unit should take into account dynamometer friction. Speed measured from dynamometer rolls should be used for all conditions.

Start the engine according to the manufacturers recommended procedure including choke setting. More choke, more throttle, etc., may be used to keep the engine running. The initial 20 s idle period begins when the engine starts. For cars equipped with automatic transmissions, the transmission should be placed in "drive" 15 s after the engine is started. Run the driving schedule in Table 1 (U.S. 1972 schedule) of SAE J1506, then after a 10 min hot soak with the engine off, repeat the schedule from 0 to 505 s.

For cars equipped with automatic transmissions, the transmission should remain in "drive" for the entire driving schedule. Wheels should be braked as necessary. For cars equipped with manual transmissions, free wheeling or overdrive units should be locked out. The vehicle should be driven with the minimum throttle movement required to maintain the desired speed.

Acceleration modes should be driven with shift speeds recommended by the manufacturer; if not specified, the vehicle should be shifted from first to second gear at 24.1 km/h (15 mph), from second to third gear at 40.2 km/h (25 mph) and if equipped with a 4-speed transmission from third to fourth gear at 64.5 km/h (40 mph). Fifth gear, if installed, should not be used. Deceleration modes should be driven with the clutch engaged, using brakes or throttle as necessary. The clutch should be depressed when speed drops below 24.1 km/h (15 mph) or when roughness is evident. Ambient air temperature during the chassis dynamometer test should be between 20 and 30 °C (68 and 86 °F).