

**Measurement of Fuel Evaporative Emissions from Gasoline Powered Passenger Cars
and Light Trucks Using the Enclosure Technique**

Foreword—This Document has also changed to comply with the new SAE Technical Standards Board format. Definitions changed to Section 3. All other section numbers have changed accordingly.

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

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:

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX: (724) 776-0790
SAE WEB ADDRESS <http://www.sae.org>

- 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 Publication—The following publication forms a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1094—Constant Volume Sampler System for Exhaust Emissions Measurement

2.2 Other Publications

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"

3. Definitions—The following definitions apply to the terms used:

- 3.1 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).
- 3.2 Evaporative Emissions**—Evaporative emissions are fuel vapors emitted into the atmosphere from the vehicle.
- 3.3 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.
- 3.4 System or Device**—System or device includes any vehicle modifications that control or reduce the amount of fuel vapors emitted from the vehicle.
- 3.5 Controlled Vehicle**—Controlled vehicle means a vehicle equipped with systems or devices to reduce the amount of evaporative emissions.
- 3.6 Hot Soak Losses**—Hot soak losses are fuel vapors emitted during a specified period beginning immediately after the engine is turned off.
- 3.7 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.
- 3.8 Running Losses**—Running losses are fuel vapors emitted during operation of the vehicle under the specified test schedule.

3.9 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).

4. 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.

4.1 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.

4.2 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.

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 ($\pm 5\%$), 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).

- 5. 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.
- 5.1 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.
- 5.2 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.
- 5.3 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 m³/min (5000 and 5600 ft³/min). Additional cooling may be used if necessary to simulate road conditions.
- 5.4 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.
- 5.5 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.
- 6. 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.
- 6.1 Equipment Requirements**—An enclosure with internal dimensions of 3 x 6 x 2.6 m (10 x 20 x 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 fluoride¹ 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."

1. "Tedlar" or equivalent.

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.

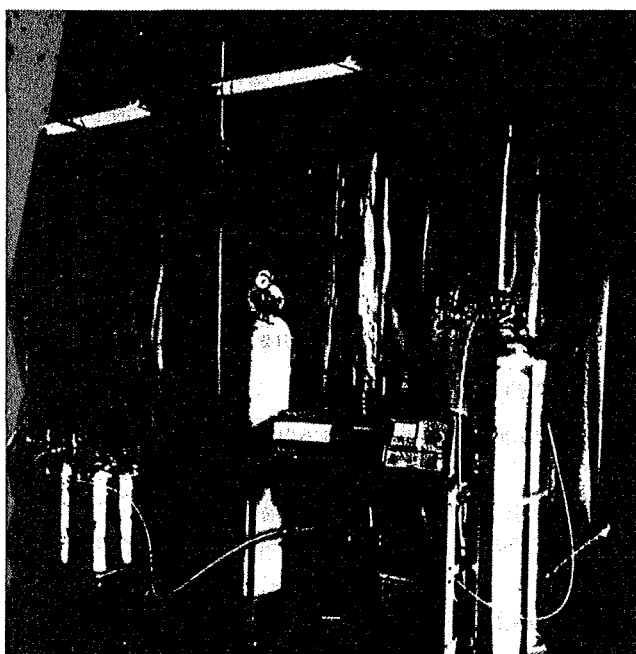
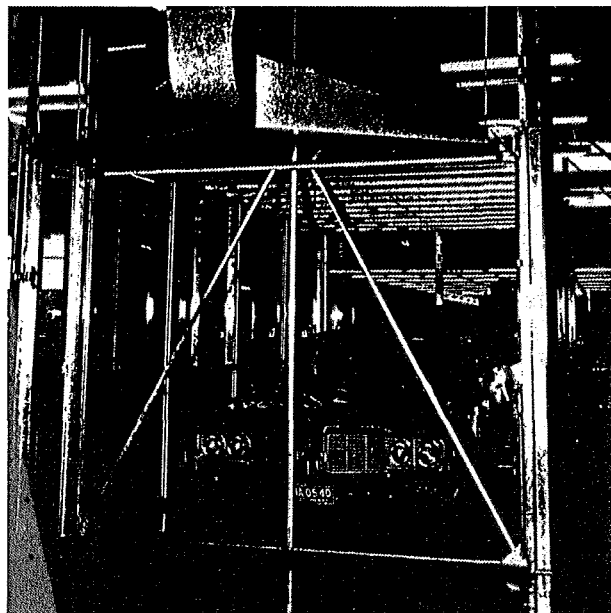


FIGURE 1—CAR ENCLOSURE

The enclosure must be equipped with a flame ionization detector (FID) hydrocarbon analyzer² capable of measuring hydrocarbon concentrations reliably in the range of 10 to 3000 ppm carbon.

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.

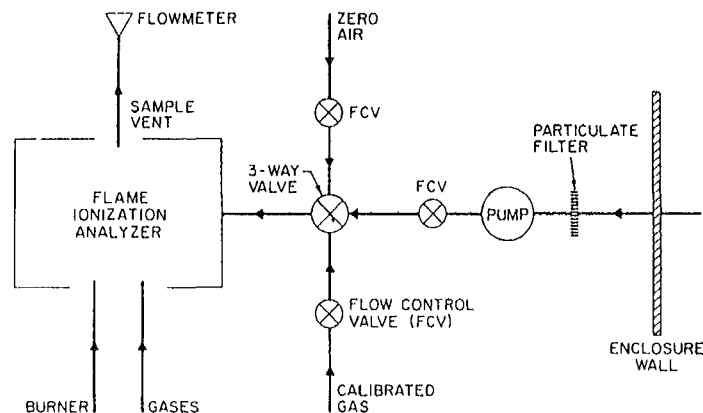


FIGURE 2—FID SAMPLE TRAIN

A blower (portable or fixed) of 42.5 to 158.6 m³/min (1500 to 5600 ft³/min) capacity is required for purging the enclosure between tests, and one or more explosion-resistant blowers of 2.8 to 28 m³/min (100 to 1000 ft³/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.

6.1.1 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.

6.2 Operating Sequence for Vehicle Soak in Enclosure

6.2.1 Zero and calibrate gas analyzer.

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

6.2.3 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.

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.

- 6.2.4 Start mixing blower and orient it such that it does not discharge directly against the vehicle.
- 6.2.5 Close and seal door. Obtain a stable initial reading of FID analyzer. Read enclosure interior air temperature and barometric pressure.
- 6.2.6 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.
- 6.2.7 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.
- 6.3 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 ($^{\circ}R$), 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 x 3. Derivation of this equation is shown in Appendix B.

- 6.4 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.
- 7. 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.
- 7.1 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.
- 7.2 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.