

RECOMMENDED PRACTICE
for
DETERMINATION OF EVAPORATIVE EMISSIONS
from
LIGHT DUTY VEHICLES
APRIL, 1976



OFFICE OF MOBILE SOURCE AIR POLLUTION CONTROL
ANN ARBOR, MICHIGAN

**Recommended Practice
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105 INTRODUCTION, STRUCTURE OF RECOMMENDED PRACTICE.

(a) This Recommended Practice describes the equipment required and the procedures to follow in order to perform exhaust and evaporative emission tests on light duty vehicles and light duty trucks.

(b) Three topics are addressed in this Recommended Practice. Sections 106 through 115 set forth specifications and equipment requirements; sections 116 through 126 discuss calibration methods and frequency; test procedures and data requirements are listed (in approximately order of performance) in sections 127 through 145.

106 EQUIPMENT REQUIRED; OVERVIEW.

(a) This Recommended Practice contains procedures for both exhaust and evaporative emissions tests on diesel or gasoline fueled light duty vehicles and light duty trucks. Certain items of equipment are not necessary for a particular test, e.g., evaporative enclosure when testing diesel vehicles. Equipment required and specifications are as follows:

(1) Evaporative emission tests, gasoline fueled vehicles. The evaporative emission test is closely related to and connected with the exhaust emission test. All vehicles tested for evaporative emissions must be tested for exhaust emissions. (Diesel vehicles are excluded from the evaporative emission standard.) Section 107 specifies the necessary equipment.

(2) Exhaust emission tests. All vehicles subject to this Recommended Practice are tested for exhaust emissions. Diesel and gasoline fueled vehicles are tested identically with the exception of hydrocarbon measurements; diesel vehicles require a heated hydrocarbon detector, section 109. All gasoline fueled vehicles are either tested for evaporative emissions or undergo a diurnal heat build, diesel vehicles are excluded from this requirement. Equipment necessary and specifications appear in sections 108 through 114.

(3) Fuel, analytical gas, and driving schedule specifications. Fuel specifications for exhaust and evaporative emission testing and for mileage accumulation for gasoline and diesel fueled vehicles are specified in section 113. Analytical gases are specified in section 114. The EPA Urban Dynamometer Driving Schedule for use in exhaust testing is specified in section 115 and Appendix I of the Federal Register.

107 SAMPLING AND ANALYTICAL SYSTEM, EVAPORATIVE EMISSIONS.

(a) Component description (evaporative emissions sampling system). The following components will be used in evaporative emissions sampling systems for testing under this Recommended Practice.

(1) Evaporative emission measurement enclosure. The enclosure shall be readily sealable, rectangular in shape, with space for personnel access to all sides of the vehicle. When sealed, the enclosure shall be gas tight in accordance with section 117. Interior surfaces must be impermeable to hydrocarbons. One surface should be of flexible, impermeable material to allow for minor volume changes, resulting from temperature changes. Wall design should promote maximum dissipation of heat, and if artificial cooling is used, interior surface temperatures shall not be less than 68°F(20°C).

(2) Evaporative emission hydrocarbon analyzers. A hydrocarbon analyzer utilizing the hydrogen flame ionization principle (FID) shall be used to monitor the atmosphere within the enclosure. Instrument bypass flow may be returned to the enclosure. The FID shall have a response time to 90% of final reading of less than 1.5 s, and be capable of meeting performance requirements expressed as a function of C_{std} ; where C_{std} is the specific enclosure hydrocarbon level, in ppm, corresponding to the evaporative emission standard:

(i) Stability of the analyzer shall be better than 0.01 C_{std} ppm at both zero and $C_{std} \pm 5$ ppm over a 15 minute period on all ranges used;

(ii) Repeatability of the analyzer, expressed as one standard deviation, shall be better than 0.005 C_{std} ppm at both zero and $C_{std} \pm 5$ ppm on all ranges used.

(3) Evaporative emission hydrocarbon data recording system. The electrical output of the FID shall be recorded at least at the initiation and termination of each diurnal or hot soak. The recording may be by means of a strip chart potentiometric recorder, by use of an on-line computer system or other suitable means. In any case, the recording system must have operational characteristics (signal to noise ratio, speed of response, etc.) equivalent to or better than those of the signal source being recorded, and must provide a permanent record of results. The record shall show a positive indication of the initiation and completion of each diurnal or hot soak along with the time elapsed between initiation and completion of each soak.

(4) Tank fuel heating system. The tank fuel heating system shall consist of a heat source and a temperature controller. A typical heat source is a 2000 w heating pad. Other sources may be used as required by circumstances. The temperature controller may be manual, such as a variable voltage transformer, or may be automated. The heating system must not cause hot spots on 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. The temperature controller must be capable of controlling the fuel tank temperature during the diurnal soak to within $\pm 3^\circ\text{F}$ (1.7°C) of the following equation:

$$F = T_o + 0.4 t$$

or for SI units:

$$C = T_o + (2/9)t$$

Where:

F = Temperature in °F
C = Temperature in °C
t = Time since start of test in minutes
T_o = Initial temperature

(5) Temperature recording system. Strip chart recorder(s) or automatic data processor shall be used to record enclosure ambient and vehicle fuel tank temperature during the evaporative emissions test. The temperature recorder or data processor shall record each temperature at least once every minute. The recording system shall be capable of resolving time to ± 15 s and capable of resolving temperature to $\pm 0.75^\circ\text{F}$ (0.42°C). The temperature recording system (recorder and sensor) shall have an accuracy of $\pm 2^\circ\text{F}$ (1.1°C). The recorder (data processor) shall have a time accuracy of ± 15 s and a precision of ± 15 s. Two ambient temperature sensors, connected to provide one average output, shall be located in the enclosure. These sensors shall be located at the approximate vertical centerline of each side wall extending 4 inches (nominally) into the enclosure at a height of 3 ± 0.5 ft (0.9 ± 0.2 m). The vehicle fuel tank temperature sensor shall be located in the fuel tank so as to measure the temperature of the prescribed test fuel at the approximate mid-volume of the fuel. Vehicles furnished for testing at Federal certification facilities shall be equipped with iron-constantan Type J thermocouples for measurement of fuel tank temperature.

(6) Purge blower. One or more portable or fixed blowers shall be used to purge the enclosure. The blowers shall have sufficient flow capacity to reduce the enclosure hydrocarbon concentration from the test level to the ambient level between tests. Actual flow capacity will depend upon the time available between tests.

(7) Mixing blower. One or more small blowers or fans with a total capacity of 200 to 600 cfm shall be used to mix the contents of the enclosure during evaporative emission testing. No portion of the air stream shall be directed towards the vehicle. Maintenance of uniform concentrations throughout the enclosure is important to the accuracy of the test.

108 DYNAMOMETER.

The dynamometer shall have a power absorption unit for simulation of road load power and flywheels or other means of simulating the inertia weight as specified in section 129.

109 EXHAUST GAS SAMPLING SYSTEM.

(a) (1) General. The exhaust gas sampline system is designed to measure the true mass emissions of vehicle exhaust. In the CVS concept of measuring mass emissions, two conditions must be satisfied; the total volume of the mixture of exhaust and dilution air must be measured, and a continuously proportioned sample of volume must be collected for analysis. Mass emissions are determined from the sample concentration and totalized flow over the test period.

(2) Positive Displacement Pump. The Positive Displacement Pump-Constant Volume Sampler (PDP-CVS), Figure 1 satisfies the first condition by metering at a constant temperature and pressure through the pump. The total volume is measured by counting the revolutions made by the calibrated positive displacement pump. The proportional sample is achieved by sampling at a constant flow rate.

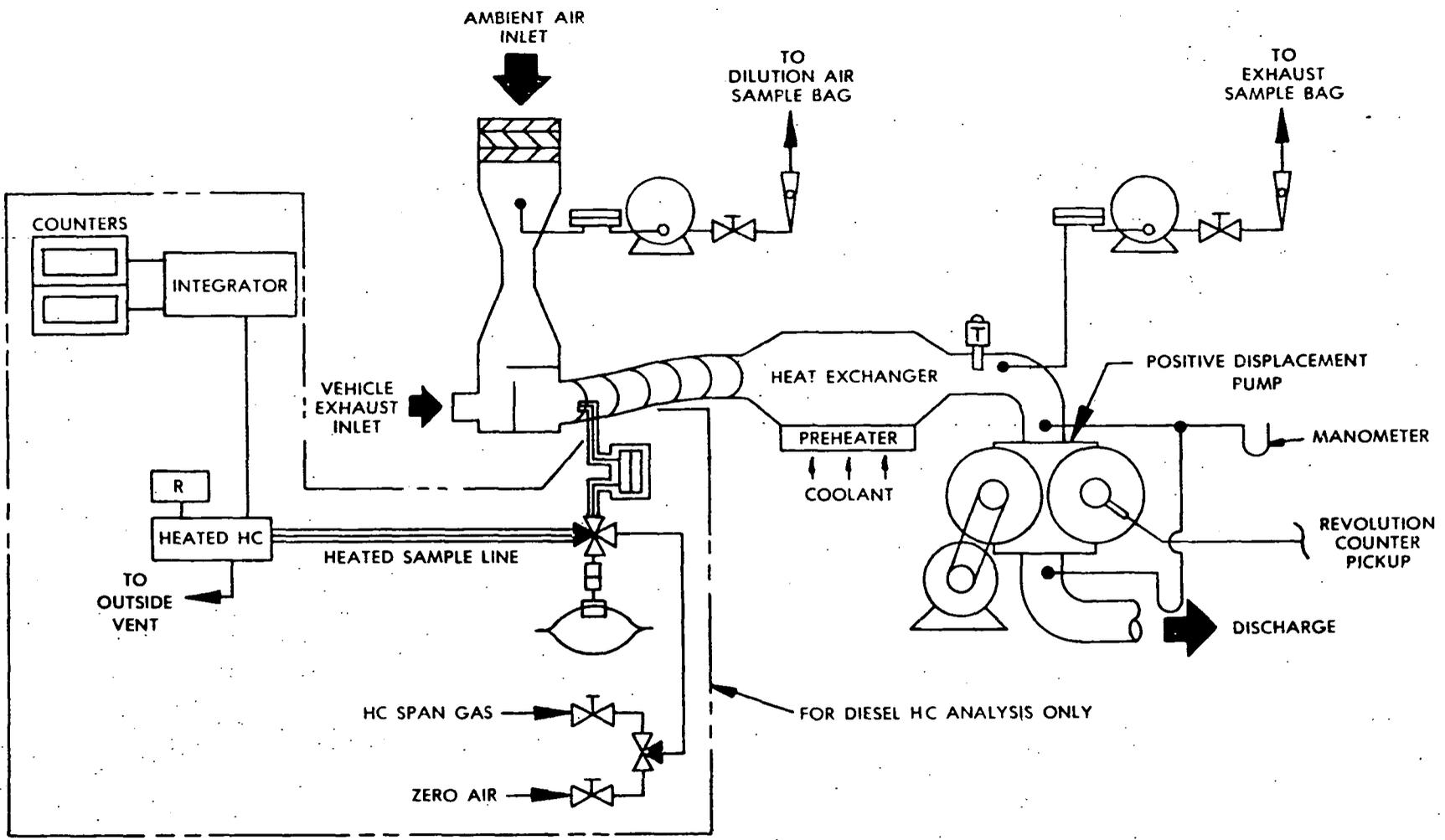
(3) Critical Flow Venturi. The operation of the Critical Flow Venturi-Constant Volume Sampler (CFV-CVS), Figure 2, is based upon the principles of fluid dynamics associated with critical flow. Proportional sampling throughout temperature excursions is maintained by use of a small CFV in the sample line. The variable mixture flow rate is maintained at sonic velocity, which is directly proportional to the square root of the gas temperature, and is computed continuously. Since the pressure and temperature are the same at both venturi inlets, the sample volume is proportional to the total volume.

(4) Diesel sampling. Diesel vehicles require a heated flame ionization detector (HFID) for hydrocarbon analysis. The sample must be taken as close as practical to the mixing point of the dilution air and exhaust sample. The HFID, by design, draws its sample at a constant flow rate. Unless compensation for varying flow is made the HFID must be used with a constant flow system to insure a representative sample.

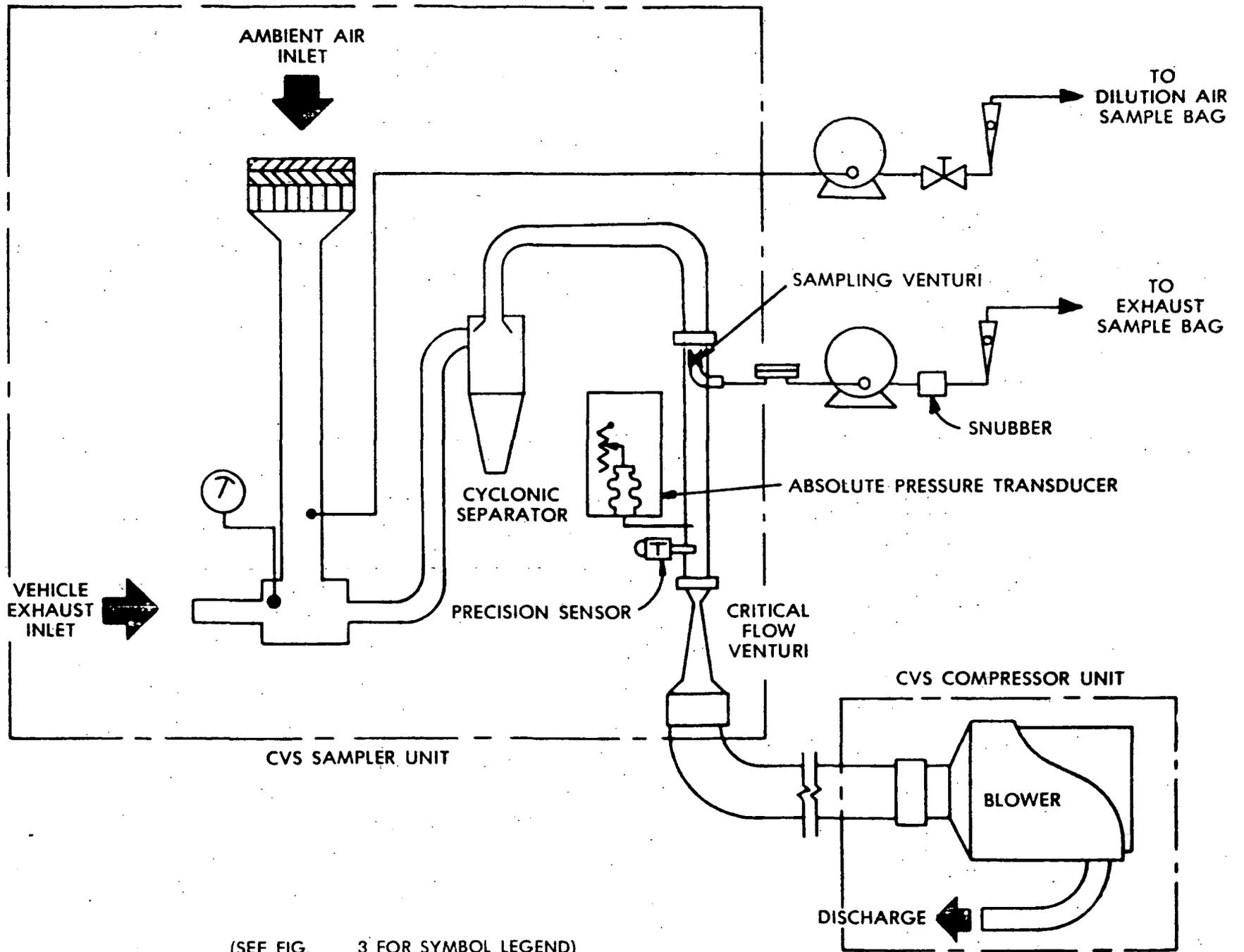
(5) Other systems. Other sampling systems may be used if shown to yield equivalent results (e.g., a heat exchanger with the CFV-CVS; an electronic flow integrator without a heat exchanger, with the PDP-CVS; or, for diesel HC measurements, an electronic flow compensator with the CFV-CVS).

(b) Component description, PDP-CVS. The PDP-CVS, Figure 1, consists of a dilution air filter and mixing assembly, heat exchanger, positive displacement pump, sampling system, and associated valves, pressure and temperature sensors.

The PDP-CVS shall conform to the following requirements:



(SEE FIG. 3 FOR SYMBOL LEGEND)
FIGURE 1—EXHAUST GAS SAMPLING SYSTEM (PDP-CVS)



(SEE FIG. 3 FOR SYMBOL LEGEND)
FIGURE 2—EXHAUST GAS SAMPLING SYSTEM (CFV-CVS)

(c) Component description, CFV-CVS. The CFV-CVS, Figure 2 consists of a dilution air filter and mixing assembly, cyclone particulate separator, sampling venturi, critical flow venturi, sampling system, and assorted valves, pressure and temperature sensors.

The CFV-CVS shall conform to the following requirements:

(1) Static pressure variations at the tailpipe(s) of the vehicle shall remain within ± 5 inches of water (1.2 kPa) of the static pressure variations measured during a dynamometer driving cycle with no connection to the tailpipe(s). (Sampling systems capable of maintaining the static pressure to within ± 1 inch of water (0.25 kPa) will be used if there is a need for this closer tolerance.)

(2) The temperature measuring system shall have an accuracy and precision of $\pm 2^\circ\text{F}$ (1.1°C) and a response time of 0.100 s to 62.5% of a temperature change.

(3) The pressure measuring system shall have an accuracy and precision of ± 3 mm Hg (0.4 kPa).

(4) The flow capacity of the CVS shall be large enough to virtually eliminate water condensation in the system (300 to 350 cfm, 0.142 to 0.165 m³/s, is sufficient for most vehicles).

(5) Sample collection bags for dilution air and exhaust samples shall be of sufficient size so as not to impede sample flow.

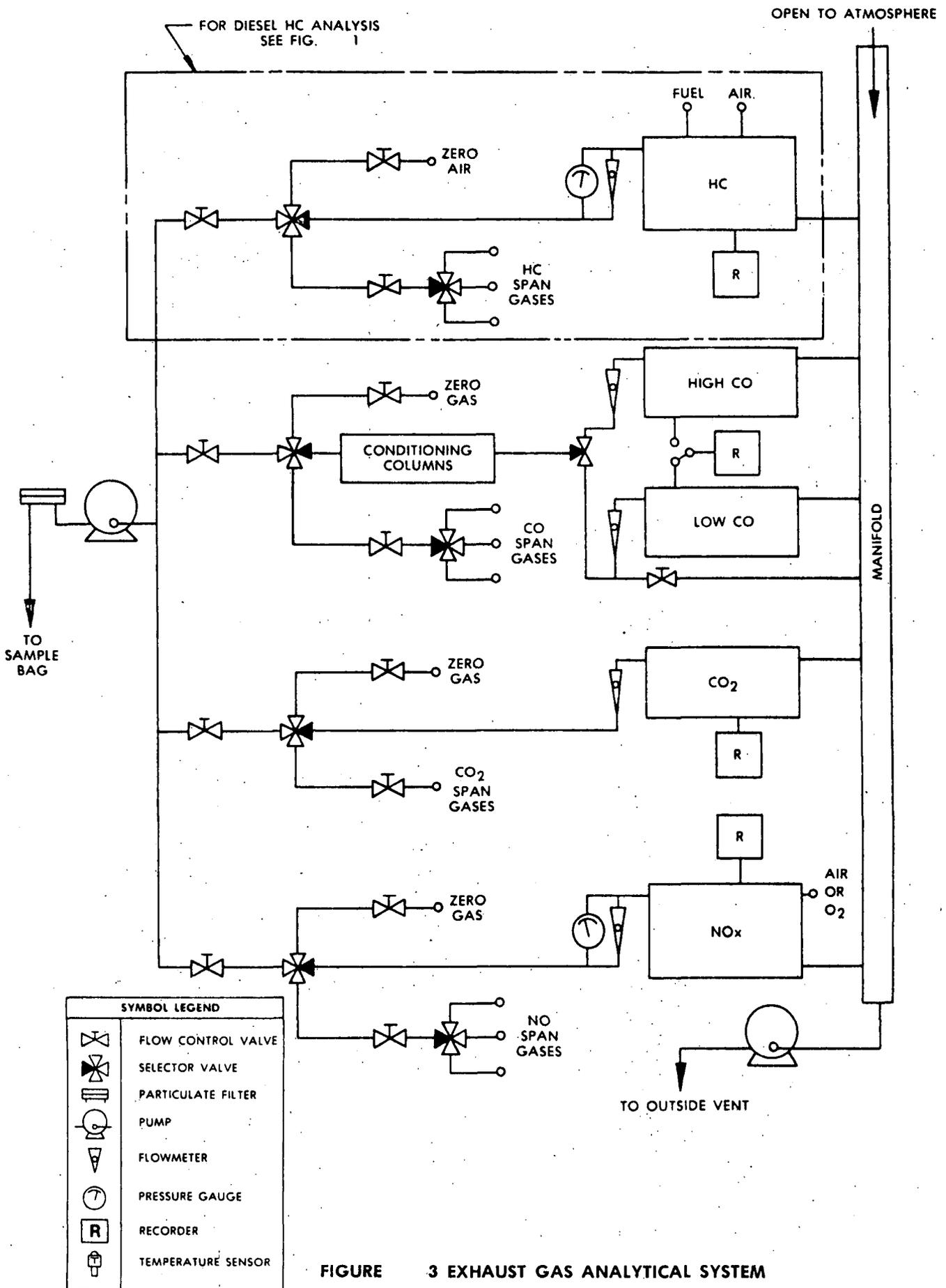
110 RESERVED.

111 EXHAUST GAS ANALYTICAL SYSTEM.

(a) Schematic drawings. Figure 3 is a schematic drawing of the exhaust gas analytical system. The schematic of the hydrocarbon analysis train for diesel fueled vehicles is shown as part of Figure 1. Since various configurations can produce accurate results, exact conformance with either drawing is not required. Additional components such as instruments, valves, solenoids, pumps and switches may be used to provide additional information and coordinate the functions of the component systems.

(b) Major component description. The analytical system, Figure 3, consists of a flame ionization detector (FID) for the determination of hydrocarbons, nondispersive infrared analyzers (NDIR) for the determination of carbon monoxide and carbon dioxide and a chemiluminescence analyzer (CL) for the determination of oxides of nitrogen. A heated flame ionization detector (HFID) is used for the continuous determination of hydrocarbons from diesel fueled vehicles, Figure 1.

The exhaust gas analytical system shall conform to the following requirements:



(1) The chemiluminescence analyzer requires that the nitrogen dioxide present in the sample be converted to nitric oxide before analysis. Other types of analyzers may be used if shown to yield equivalent results.

(2) The carbon monoxide (NDIR) analyzer may require a sample conditioning column containing CaSO_4 , or indicating silica gel to remove water vapor and containing ascarite to remove carbon dioxide from the CO analysis stream.

(i) If CO instruments which are essentially free of CO_2 and water vapor interference are used, the use of the conditioning column may be deleted, see sections 122 and 144.

(ii) A CO instrument will be considered to be essentially free of CO_2 and water vapor interference if its response to a mixture of 3 percent CO_2 in N_2 which has been bubbled through water at room temperature produces an equivalent CO response, as measured on the most sensitive CO range, which is less than 1 percent of full scale CO concentration on ranges above 300 ppm full scale or less than 3 ppm on ranges below 300 ppm full scale, see section 122.

(3) For diesel fueled vehicles a continuous sample shall be measured using a heated analyzer train as shown in Figure 1. The train shall include a heated continuous sampling line, a heated particulate filter and a heated hydrocarbon instrument (HFID) complete with heated pump, filter and flow control system.

(i) The response time of this instrument shall be less than 1.5 seconds for 90 percent of full-scale response.

(ii) Sample transport time from sampling point to inlet of instrument shall be less than 4 seconds.

(iii) The sample line and filter shall be heated to a set point $\pm 10^\circ\text{F}$ ($\pm 5.6^\circ\text{C}$) between 300 and 390°F (149 and 199°C).

(c) Other analyzers and equipment. Other types of analyzers and equipment may be used if shown to yield equivalent results.

112 RESERVED.

113 FUEL SPECIFICATIONS.

(a) Gasoline.

(1) Gasoline having the following specifications shall be used in exhaust and evaporative emission testing.

| Item | ASTM | Leaded | Unleaded |
|--|-------|------------------|-----------|
| Octane, research, minimum | D2699 | 100 | 96 |
| Pb. (organic), grams/U.S. gallon | | 1.4 ¹ | 0.00-0.05 |
| Distillation range: | | | |
| IBP ² , °F | D86 | 75-95 | 75-95 |
| 10 percent point, °F | D86 | 120-135 | 120-135 |
| 50 percent point, °F | D86 | 200-230 | 200-230 |
| 90 percent point, °F | D86 | 300-325 | 300-325 |
| EP, °F (maximum) | D86 | 415 | 415 |
| Sulphur, weight percent, | | | |
| maximum | D1266 | 0.10 | 0.10 |
| Phosphorus, grams/U.S. gallon, maximum | | | |
| | | 0.01 | 0.005 |
| RVP ^{3,4} , psi | D323 | 8.7-9.2 | 8.7-9.2 |
| Hydrocarbon composition | | | |
| Olefins, percent, maximum | D1319 | 10 | 10 |
| Aeromatics, percent, | | | |
| maximum | D1319 | 35 | 35 |
| Saturates | D1319 | (5) | (5) |

- 1 Minimum.
- 2 For testing at altitudes above 1,219 meters (4,000 feet) the specified range is 75-105.
- 3 For testing which is unrelated to evaporative emission control, the specified range is 8.0-9.2.
- 4 For testing at altitudes above 1,219 meters (4,000 feet) the specified range is 7.9-9.2.

(2) Gasoline representative of commercial gasoline which will be generally available through retail outlets shall be used in service accumulation. For leaded gasoline the minimum lead content shall be 1.4 grams per U.S. gallon. The octane rating of the gasoline used shall be no higher than 4.0 research octane numbers above the minimum recommended by the vehicle manufacturer. The Reid Vapor Pressure of the gasoline used shall be characteristic of the motor fuel used during the season in which the service accumulation takes place.

(3) The specification range of the gasoline to be used under paragraph (a)(2) of this section shall be reported.

(b) Diesel fuel.

(1) The diesel fuels employed for testing shall be clean and bright, with pour and cloud points adequate for operability. The

diesel fuel may contain nonmetallic additives as follows: Centane improver, metal deactivator, antioxidant, dehazer, antirust, pour depressant, dye, and dispersant.

(2) Diesel fuel meeting the following specifications, or substantially equivalent specifications shall be used in exhaust emissions testing. The grade of diesel fuel recommended by the engine manufacturer commercially designated as "Type 1-D" or "Type 2-D", shall be used.

| Item | ASTM | Type 1-D | Type 2-D |
|-------------------------------|---------------|-----------|----------|
| Cetane | D613 | 48-54 | 42-52 |
| Distillation range | D86 | | |
| IBP, °F | | 330-390 | 340-400 |
| 10 percent point, °F | | 370-430 | 400-460 |
| 50 percent point, °F | | 410-480 | 470-540 |
| 90 percent point, °F | | 460-520 | 550-610 |
| EP, °F | | 500-560 | 580-660 |
| Gravity, °API | D287 | 40-44 | 33-37 |
| Total Sulfur, percent | D129 or D2622 | 0.05-0.20 | 0.2-0.5 |
| Hydrocarbon composition | D1319 | | |
| Aromatics, percent | | 8-15 | 27 (1) |
| Paraffins, Naphtenes, Olefins | | (2) | (2) |
| Flashpoint, °F (minimum) | D93 | 120 | 130 |
| Viscosity, Centistokes | D445 | 1.6-2.0 | 2.0-3.2 |

1 Minimum

2 Remainder

(3) Diesel fuel meeting the following specifications, or substantially equivalent specifications shall be used in service accumulation. The grade of diesel fuel recommended by the engine manufacturer, commercially designated as "Type 1-D" or "Type 2-D", shall be used.

| Item | ASTM | Type 1-D | Type 2-D |
|--------------------------|---------------|-----------|----------|
| Cetane | D613 | 48-54 | 42-55 |
| Distillation range | D86 | | |
| IBP, °F | | 330-390 | 340-410 |
| 10 percent point, °F | | 370-430 | 400-470 |
| 50 percent point, °F | | 410-480 | 470-540 |
| 90 percent point, °F | | 460-520 | 550-610 |
| EP, °F | | 500-560 | 580-660 |
| Gravity, °API | D287 | 40-44 | 33-40 |
| Total Sulfur, percent | D129 or D2622 | 0.05-0.20 | 0.2-0.5 |
| Flashpoint, °F (minimum) | D93 | 120 | 130 |
| Viscosity, Centistokes | D445 | 1.6-2.0 | 2.0-3.2 |

(4) Other petroleum distillation fuel specifications:

(i) Other petroleum distillate fuels may be used for testing and service accumulation provided they are commercially available, and

(ii) Information is provided to show that only the designated fuel would be used in customer service, and

(iii) Use of a fuel listed under paragraphs (b)(2) and (b)(3) of this section would have a detrimental effect on emissions or durability.

(5) The specification range of the fuels to be used under paragraphs (b)(2), (b)(3), and (b)(4) of this section shall be reported.

114 ANALYTICAL GASES.

(a) Analyzer gases.

(1) Gases for the CO and CO₂ analyzers shall be single blends of CO and CO₂ respectively using nitrogen as the diluent.

(2) Gases for the hydrocarbon analyzer shall be single blends of propane using air as the diluent.

(3) Gases for NO_x analyzer shall be single blends of NO named as NO_x, with a maximum NO₂ concentration of 5 percent of the nominal value, using nitrogen as the diluent.

(4) Fuel for the evaporative emission enclosure FID shall be a blend of 60 percent helium and 40 percent hydrogen containing less than 1 ppm equivalent carbon response. Other FID fuels may be used if shown to yield equivalent results.

(5) The allowable zero gas (air or nitrogen) impurity concentrations shall not exceed 1 ppm equivalent carbon response, 1 ppm carbon monoxide, 0.04 percent (400 ppm) carbon dioxide and 0.1 ppm nitric oxide.

(6) "Zero grade air" includes artificial "air" consisting of a blend of nitrogen and oxygen with oxygen concentrations between 18 and 21 mole percent.

(b) Calibration gases should be known to within ± 2 percent of the true values.

114A ANALYTICAL GASES

(This section under consideration for future applications)

(a) Analyzer gases.

(1) Gases for the CO and CO₂ analyzers shall be single blends of CO and CO₂ respectively using nitrogen as the diluent.

(2) Gases for the hydrocarbon analyzer shall be single blends of propane using air as the diluent.

(3) Gases for NO_x analyzer shall be single blends of NO named as NO_x with a maximum NO₂ concentration of 5 percent of the nominal value using nitrogen as the diluent.

(4) Fuel for the evaporative emission enclosure FID shall be a blend of 60 percent helium and 40 percent hydrogen containing less than 1 ppm equivalent carbon response. Other FID fuels may be used if shown to yield equivalent results.

(5) The allowable zero gas (air or nitrogen) impurity concentrations shall not exceed 1 ppm equivalent carbon response, 1 ppm carbon monoxide, 0.04 percent (400 ppm) carbon dioxide and 0.1 ppm nitric oxide.

(6) "Zero grade air" includes artificial "air" consisting of a blend of nitrogen and oxygen with oxygen concentrations between 18 and 21 mole percent.

(b) Calibration gases shall be traceable to within 1 percent of NBS gas standards, or other gas standards which have been approved.

(c) Span gases shall be accurate to within 2 percent of true concentration, where true concentration refers to NBS gas standards, or other gas standards which have been approved.

115 EPA URBAN DYNAMOMETER DRIVING SCHEDULE.

(a) The dynamometer driving schedule is listed in Appendix I of the Federal Register. The driving schedule is defined by a smooth trace drawn through the specified speed vs. time relationships. It consists of a non-repetitive series of idle, acceleration, cruise, and deceleration modes of various time sequences and rates.

(b) The speed tolerance at any given time on the dynamometer driving schedule prescribed in Appendix I or as printed on a driver's aid chart when conducted to meet the requirements of section 137 is defined by upper and lower limits. The upper limit is 2 mph (3.2 km/h) higher than the highest point on the trace within 1 second of the given time. The lower limit is 2 mph (3.2 km/h) lower than the lowest point on the trace within 1 second of the given time. Speed variations greater than the tolerances (such as may occur during gear changes) are acceptable provided they occur for less than 2 seconds on any occasion. Speeds lower than those prescribed are acceptable provided the vehicle is operated at maximum available power during such occurrences. When conducted to meet the requirements of section 128 the speed tolerance shall be as specified above, except that the upper and lower limits shall be 4 mph (6.4 km/h).

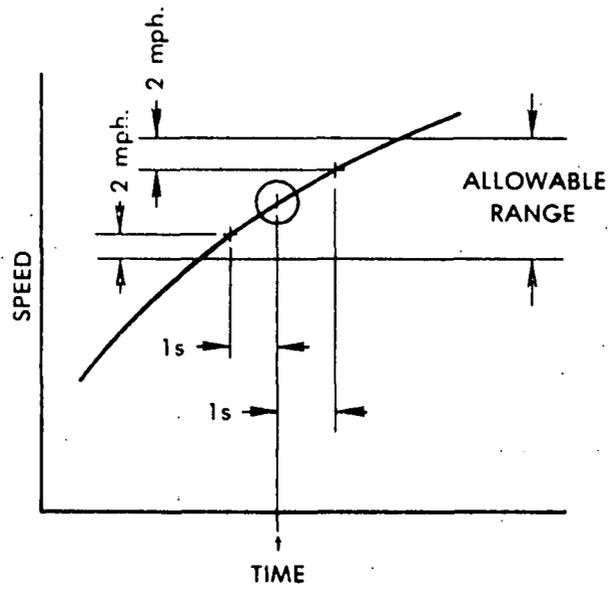


FIGURE 4a—DRIVERS TRACE, ALLOWABLE RANGE

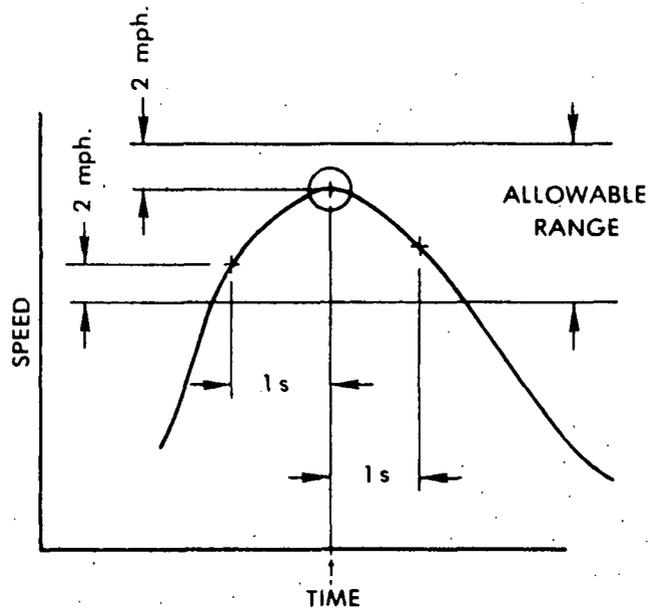


FIGURE 4b—DRIVERS TRACE, ALLOWABLE RANGE

(c) Figure 4 shows the range of acceptable speed tolerances for typical points. Figure 4(a) is typical of portions of the speed curve which are increasing or decreasing throughout the two second time interval. Figure 4(b) is typical of portions of the speed curve which include a maximum or minimum value.

116 CALIBRATIONS, FREQUENCY AND OVERVIEW.

(a) Calibrations shall be performed as specified in sections 117 through 126.

(b) At least yearly or after any maintenance which could alter background emission levels, enclosure background emission measurements shall be performed.

(c) At least monthly or after any maintenance which could alter calibration, the following calibrations and checks shall be performed:

(1) Calibrate the hydrocarbon analyzers (both evaporative and exhaust instruments), carbon dioxide analyzer, carbon monoxide analyzer, oxides of nitrogen analyzer.

(2) Calibrate the dynamometer. If the dynamometer receives a weekly performance check (and remains within calibration) the monthly calibration need not be performed.

(3) Perform a hydrocarbon retention check and calibration on the evaporative emission enclosure.

(d) At least weekly or after any maintenance which could alter calibration, the following calibrations and checks shall be performed:

(1) Check the oxides of nitrogen converter efficiency, and

(2) Perform a CVS system verification, and

(3) Run a performance check on the dynamometer. This check may be omitted if the dynamometer has been calibrated within the preceding month.

(e) The CVS positive displacement pump or Critical Flow Venturi shall be calibrated following initial installation, major maintenance or as necessary when indicated by the CVS system verification (described in section 119).

(f) Sample conditioning columns, if used in the CO analyzer train, should be checked at a frequency consistent with observed column life or when the indicator of the column packing begins to show deterioration.

117 EVAPORATIVE EMISSION ENCLOSURE CALIBRATIONS.

The calibration of the evaporative emission enclosure consists of three parts: Initial and periodic determination of enclosure background emissions; initial determination of enclosure internal volume; and periodic hydrocarbon retention check and calibration.

(a) Initial and periodic determination of enclosure background emissions. Prior to its introduction into service, annually thereafter, and after any repair which can affect the enclosure background emissions, the enclosure shall be checked to determine that it does not contain materials which will themselves emit hydrocarbons.

Proceed as follows:

- (1) Zero and span (calibrate if required) the hydrocarbon analyzer.
- (2) Purge the enclosure until a stable background hydrocarbon reading is obtained.
- (3) Turn on the mixing blower (if not already on).
- (4) Seal enclosure and measure background hydrocarbon concentration, temperature, and barometric pressure. These are the initial readings C_{HCi} , T_i and P_{Bi} for the enclosure background determination.
- (5) Allow the enclosure to stand undisturbed without sampling for four hours.
- (6) Measure the hydrocarbon concentration on the same FID. This is the final concentration, C_{HCf} . Also measure final temperature and barometric pressure.
- (7) Calculate the mass change of hydrocarbons in the enclosure according to the equations in paragraph (d). The enclosure background emissions shall not be greater than 0.4g for the 4 hours.

(b) Initial determination of enclosure internal volume. Prior to its introduction into service the enclosure internal volume shall be determined by the following procedure.

- (1) Carefully measure the internal length, width and height of the enclosure, accounting for irregularities (such as braces) and calculate the internal volume.
- (2) Perform an enclosure calibration check according to paragraph (c) steps (1) through (7).
- (3) If the calculated mass does not agree within 2% of the injected propane mass, then corrective action is required.

(c) Hydrocarbon retention check and calibration. The hydrocarbon retention check provides a check upon the calculated volume and also measures the leak rate. Prior to its introduction into service and at least monthly thereafter the enclosure leak rate shall be determined as follows:

- (1) Zero and span (calibrate if required) the hydrocarbon analyzer.
- (2) Purge the enclosure until a stable background hydrocarbon reading is obtained.
- (3) Turn on the mixing blower (if not already on).
- (4) Seal enclosure and measure background hydrocarbon concentration, temperature and barometric pressure. These are the initial readings C_{HCi} , T_i and P_{Bi} for the enclosure calibration.
- (5) Inject into the enclosure 4g (nominal value) of pure propane. The propane may be measured by volume flow or by mass measurement. The method used to measure the propane shall have an accuracy and precision of $\pm 0.5\%$ of the measured value.
- (6) After a minimum of five minutes of mixing, analyze the enclosure atmosphere for hydrocarbon content, also record temperature and pressure. These measurements are the final readings for the enclosure calibration as well as the initial readings for the retention check.
- (7) To verify the enclosure calibration calculate the mass of propane using the measurements taken in steps (4) and (6). See paragraph (d). This quantity must be within $\pm 2\%$ of that measured in step 5 above.
- (8) Allow the enclosure to remain sealed for a minimum of four hours without sampling and with the mixing blower operating. After four hours analyze the enclosure atmosphere for hydrocarbon content; record temperature and barometric pressure. These are the final readings for the hydrocarbon retention check.
- (9) Calculate, using the equations in paragraph (d) and the readings taken in (6) and (8), the hydrocarbon mass change. It must be less than 0.4 g or the enclosure cannot be used.

(d) Calculations. The calculation of net hydrocarbon mass change is used to determine enclosure background and leak rate. It is also used to check the enclosure volume measurements. The mass change is calculated from the initial and final readings of hydrocarbon concentration, temperature and pressure according to the following equation:

$$M_{HC} = k V \times 10^{-4} \left[\frac{C_{HCf} P_{Bf}}{T_f} - \frac{C_{HCi} P_{Bi}}{T_i} \right]$$

Where:

M_{HC} = hydrocarbon mass change, g

C_{HC} = hydrocarbon concentration as ppm carbon

V = enclosure volume, ft³ (m³), as measured in (b) (1) above

P_B = barometric pressure, in. Hg(kPa)

T = enclosure ambient temperature, R(K)

$k = 3.05$

for SI units, $k = 17.60$

i = indicates initial reading

f = indicates final reading

NOTE: Hydrocarbon concentration is stated in ppm carbon, that is, ppm propane x3. Expressions in parenthesis are for SI units.

118 DYNAMOMETER CALIBRATION.

(a) The dynamometer shall be calibrated at least once each month or performance verified at least once each week and then calibrated as required. The calibration shall consist of the manufacturer's recommended calibration procedure plus a determination of the dynamometer frictional power absorption at 50.0 mph (80.5 km/h). One method for determining dynamometer frictional power absorption at 50.0 mph (80.5 km/h) is described below, other methods may be used if shown to yield equivalent results. The measured absorbed road power includes the dynamometer friction as well as the power absorbed by the power absorption unit. The dynamometer is driven above the test speed range. The device used to drive the dynamometer is then disengaged from the dynamometer and the roll(s) is (are) allowed to coast down. The kinetic energy of the system is dissipated by the dynamometer. This method neglects the variations in roll bearing friction due to the drive axle weight of the vehicle. The inertia of the free (rear) roll may be neglected in the case of dynamometers with paired rolls.

(1) Devise a method to determine the speed of the drive roll if it is not already measured. A fifth wheel, revolution pickup, or other suitable means may be used.

(2) Place a vehicle on the dynamometer or devise another method of driving the dynamometer.

(3) Engage the inertial flywheel or other inertial simulation system for the most common vehicle mass category for which the dynamometer is used. In addition other vehicle mass categories may be calibrated, if desired.

(4) Drive the dynamometer up to 50.0 mph (80.5 km/h).

(5) Record indicated road power.

(6) Drive the dynamometer up to 60.0 mph (96.9 km/h).

(7) Disengage the device used to drive the dynamometer.

(8) Record the time for the dynamometer drive roll to coastdown from 55.0 mph (88.5 km/h) to 45 mph (72.4 km/h).

(9) Adjust the power absorption unit to a different level.

(10) Repeat steps 4 to 9 above sufficient times to cover the range of road power used.

(11) Calculate absorbed road power (HP_d). See paragraph (c).

(12) Plot indicated road load power at 50 mph (80.5 km/h) versus road load power at 50 mph (80.5 km/h) as shown in Figure 5.

(b) The performance check consists of conducting a dynamometer coastdown at one or more inertia-horsepower settings and comparing the coastdown time to that recorded during the last calibration. If the coastdown times differ by more than 1 s, a new calibration is required.

(c) Calculations. The road load power actually absorbed by the dynamometer is calculated from the following equation:

$$HP_d = (1/2) (W/32.2) (v_1^2 - v_2^2)/550t$$

Where:

HP_d = Power, horsepower (kilowatts)

W = Equivalent inertia, lb (Kg)

v_1 = Initial Velocity, ft/s (m/s)
(55 mph = 88.5 km/h = 80.67 ft/s = 24.58 m/s)

v_2 = Final Velocity, ft/s (m/s)
(45 mph = 72.4 km/h = 66 ft/s = 20.11 m/s)

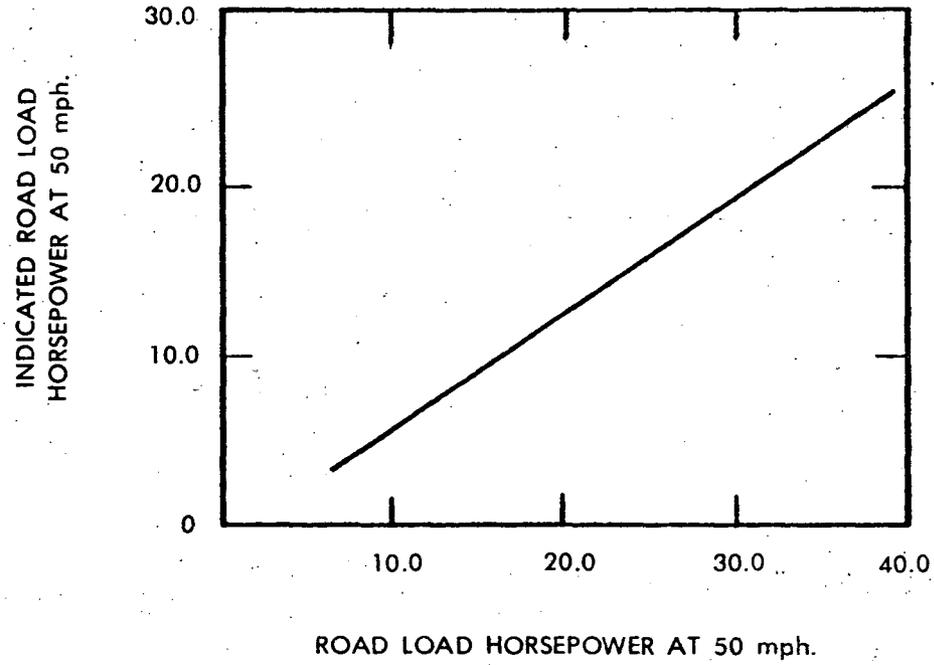


FIGURE 5—ROAD LOAD HORSEPOWER, ACTUAL VS. INDICATED

t = elapsed time for rolls to coast from 55 mph
to 45 mph (88.5 to 72.4 km/h)

(Expressions in parenthesis are for SI units.). When the coastdown is from 55 to 45 mph (88.5 to 72.4 km/h) the above equation reduces to:

$$HP_d = 0.06073 (W/t)$$

for SI units, $HP_d = 0.09984 (W/t)$

119 CVS CALIBRATION.

The CVS (Constant Volume Sampler) is calibrated using an accurate flowmeter and restrictor valve. Measurements of various parameters are made and related to flow through the unit. Procedures used for both PDP (Positive Displacement Pump) and CFV (Critical Flow Venturi) are outlined below. Other procedures yielding equivalent results may be used.

After the calibration curve has been obtained, verification of the entire system can be performed by injecting a known mass of gas into the system and comparing the mass indicated by the system to the true mass injected. An indicated error does not necessarily mean that the calibration is wrong, since other factors can influence the accuracy of the system, e.g. analyzer calibration. A verification procedure is found in paragraph (c).

(a) PDP calibration.

(1) The following calibration procedure outlines the equipment, the test configuration, and the various parameters which must be measured to establish the flow rate of the constant volume sampler pump. All the parameters related to the pump are simultaneously measured with the parameters related to a flowmeter which is connected in series with the pump. The calculated flow rate $ft^3/min.$ (at pump inlet absolute pressure and temperature) can then be plotted versus a correlation function which is the value of a specific combination of pump parameters. The linear equation which relates the pump flow and the correlation function is then determined. In the event that a CVS has a multiple speed drive, a calibration for each range used must be performed.

(2) This calibration procedure is based on the measurement of the absolute values of the pump and flowmeter parameters that relate the flow rate at each point. Three conditions must be maintained to assure the accuracy and integrity of the calibration curve. First, the pump pressures should be measured at taps on the pump rather than at the external piping on the pump inlet and outlet. Pressure taps that are mounted at the top center and bottom center of the pump drive headplate are exposed to the actual pump cavity pressures, and therefore reflect the absolute pressure differentials. Secondly, temperature stability must be maintained during the calibration. The laminar flowmeter is

sensitive to inlet temperature oscillations which cause the data points to be scattered. Gradual changes ($\pm 2^\circ\text{F}$ (1.1°C)) in temperature are acceptable as long as they occur over a period of several minutes. Finally, all connections between the flowmeter and the CVS pump must be absolutely void of any leakage.

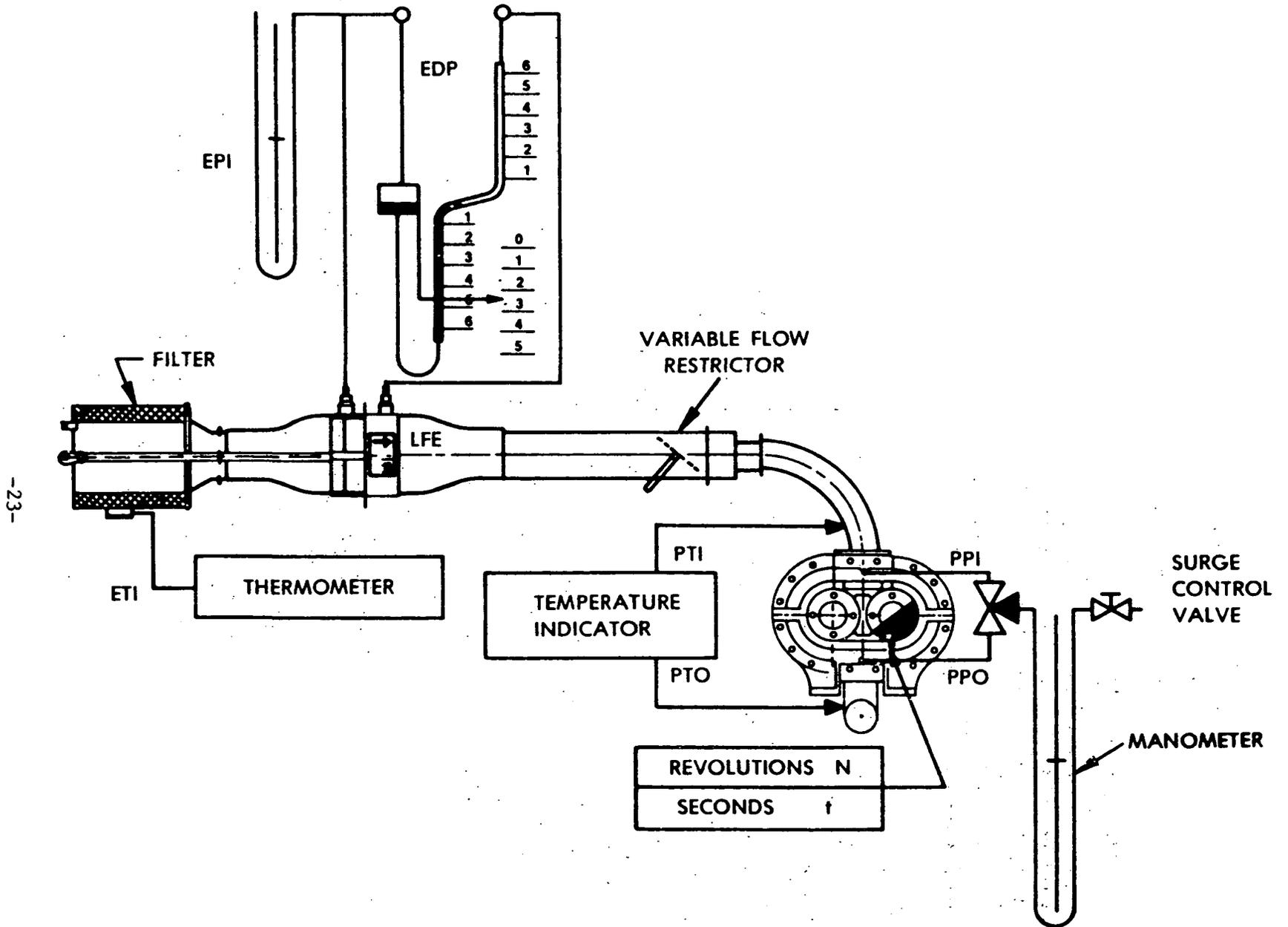
(3) During an exhaust emission test the measurement of these same pump parameters enables the user to calculate the flow rate from the calibration equation.

(4) Connect a system as shown in Figure 6. Although particular types of equipment are shown, other configurations that yield equivalent results may be used. For the system indicated, the following data with given accuracy are required:

CALIBRATION DATA MEASUREMENTS

| PARAMETER | SYM | UNITS | TOLERANCES |
|--|--------------|---------------------------------------|---|
| Barometric pressure (corrected) | P_B | in. Hg (kPa) | ± 0.01 in. Hg (± 0.034 kPa) |
| Ambient temperature | T_B | $^\circ\text{F}$ ($^\circ\text{C}$) | $\pm 0.5^\circ\text{F}$ ($\pm 0.28^\circ\text{C}$) |
| Air temperature into LFE | T_A ETI | $^\circ\text{F}$ ($^\circ\text{C}$) | $\pm 0.25^\circ\text{F}$ ($\pm 0.14^\circ\text{C}$) |
| Pressure depression upstream of LFE | EPI | in. H_2O (kPa) | ± 0.05 in. H_2O (± 0.012 kPa) |
| Pressure drop across the LFE matrix | EDP | in. H_2O (kPa) | ± 0.005 in. H_2O (± 0.001 kPa) |
| Air temperature at CVS pump inlet | PTI | $^\circ\text{F}$ ($^\circ\text{C}$) | $\pm 0.5^\circ\text{F}$ ($\pm 0.28^\circ\text{C}$) |
| Pressure depression at CVS pump inlet | PPI | in. Fluid (kPa) | ± 0.05 in. Fluid (± 0.022 kPa) |
| Specific gravity of manometer fluid (1.75 oil) | Sp. Gr. | - | - |
| Pressure head at CVS pump outlet | PPO | in. Fluid (kPa) | ± 0.05 in. Fluid (± 0.022 kPa) |
| Air temperature at CVS pump outlet (optional) | PTO | $^\circ\text{F}$ ($^\circ\text{C}$) | $\pm 0.5^\circ\text{F}$ ($\pm 0.28^\circ\text{C}$) |
| Pump revolutions during test period | N | Revs | ± 1 Rev. |
| Elapsed time for test period | t | s | ± 0.05 s |

(5) After the system has been connected as shown in Figure 6, set the variable restrictor in the wide open position and run the CVS pump for twenty minutes. Record the calibration data.



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FIGURE 6—PDP-CVS CALIBRATION CONFIGURATION

(6) Reset the restrictor valve to a more restricted condition in an increment of pump inlet depression (about 4" H₂O (1.0 kPa) that will yield a minimum of six data points for the total calibration. Allow the system to stabilize for 3 minutes and repeat the data acquisition.

(7) Data analysis:

(i) The air flow rate, Q_s, at each test point is calculated in standard cubic feet per minute from the flowmeter data using the manufacturer's prescribed method.

(ii) The air flow rate is then converted to pump flow, V_o, in cubic feet per revolution at absolute pump inlet temperature and pressure.

$$V_o = \frac{Q_s}{n} \times \frac{T_p}{528} \times \frac{29.92}{P_p}$$

Where:

V_o = Pump flow, ft³/ revolution (m³/revolution) at T_p, P_p

Q_s = Meter air flow rate in standard cubic feet per minute, standard conditions are 68°F, 29.92 in. Hg (20°C, 101.3 kPa).

n = Pump speed in revolutions per minute.

T_p = Pump inlet temperature, R(K)

P_p = PTI + 460

for SI units, T_p = PTI + 273

P_p = Absolute pump inlet pressure, in. Hg (kPa)

P_p = P_B - PPI (SP.GR./13.57)

for SI units, P_p = P_B - PPI

Where:

P_B = barometric pressure, in. Hg (kPa)

PPI = Pump inlet depression, in. fluid (kPa)

SP. GR. = Specific gravity of manometer fluid relative to water.

(iii) The correlation function at each test point is then calculated from the calibration data:

$$X_o = \frac{1}{n} \sqrt{\frac{\Delta P_p}{P_e}}$$

Where:

X_o = correlation function.

ΔP_p = The pressure differential from pump inlet to pump outlet, in. Hg (kPa)
 $= P_e - P_p$

P_e = Absolute pump outlet pressure, in. Hg (kPa)
 $= P_B + PPO$ (SP. GR./13.57)
 for SI units, $P_e = P_B + PPO$

Where:

PPO = Pressure head at pump outlet, in. fluid (kPa)

(iv) A linear least squares fit is performed to generate the calibration equations which have the forms:

$$V_o = D_o - M(X_o)$$

$$n = A - B(\Delta P_p)$$

D_o , M , A , and B are the slope-intercept constants describing the lines.

(8) A CVS system that has multiple speeds should be calibrated on each speed used. The calibration curves generated for the ranges will be approximately parallel and the intercept values, D_o , will increase as the pump flow range decreases.

(9) If the calibration has been performed carefully, the calculated values from the equation will be within +0.50% of the measured value of V_o . Values of M will vary from one pump to another, but values of D_o for pumps of the same make, model, and range should agree within $\pm 3\%$ of each other. Particulate influx from use will cause the pump slip to decrease as reflected by lower values for M . Calibrations should be performed at pump start-up and after major maintenance to assure the stability of the pump slip rate. Analysis of mass injection data will also reflect pump slip stability.

(b) CFV calibration.

(1) Calibration of the Critical Flow Venturi (CFV) is based upon the flow equation for a critical venturi. Gas flow is a function of inlet pressure and temperature:

$$Q_s = \frac{K_v P}{\sqrt{T}}$$

Where:

- Q_s = Flow
- K_s = Calibration coefficient
- P = Absolute pressure
- T = Absolute temperature

The calibration procedure described below establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow.

(2) The manufacturer's recommended procedure shall be followed for calibrating electronic portions of the CFV.

(3) Measurements necessary for flow calibration are as follows:

| CALIBRATION DATA MEASUREMENTS | | | |
|---|---------|--|---|
| PARAMETER | SYM | UNITS | TOLERANCES |
| °Barometric Pressure (corrected) | P_B | in. Hg (kPa) | $\pm .01$ in. Hg ($\pm .034$ kPa) |
| °Air temperature, flowmeter | ETI | °F (°C) | $\pm .25$ °F ($\pm .14$ °C) |
| °Pressure depression upstream of LFE | EPI | in. H ₂ O (kPa) | $\pm .05$ in. H ₂ O ($\pm .012$ kPa) |
| °Pressure drop across LFE matrix | EDP | in. H ₂ O (kPa) | $\pm .005$ in. H ₂ O ($\pm .001$ kPa) |
| °Air flow | Q_s | ft ³ /min. (m ³ /min.) | $\pm .5\%$ |
| °CFV inlet depression | PPI | in. fluid (kPa) | $\pm .05$ in. fluid ($\pm .022$ kPa) |
| °Temperature at venturi inlet | T_v | °F (°C) | $\pm .5$ °F ($\pm .28$ °C) |
| °Specific gravity of manometer fluid (1.75 oil) | Sp. Gr. | - | - |

(4) Set up equipment as shown in Figure 7 and check for leaks. Any leaks between the flow measuring device and the critical flow venturi will seriously affect the accuracy of the calibration.

(5) Set the variable flow restrictor to the open position, start the blower and allow the system to stabilize. Record data from all instruments.

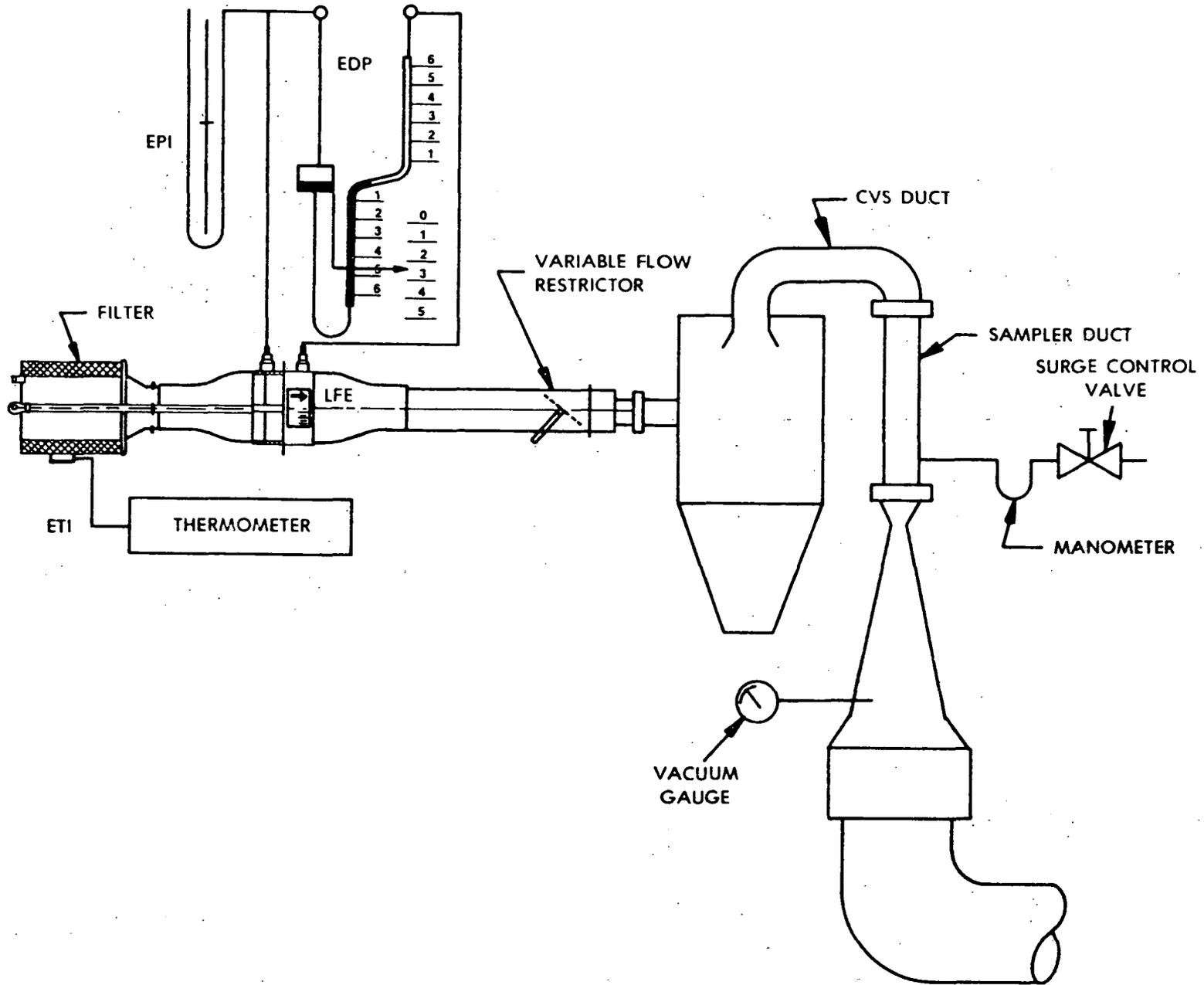


FIGURE 7 CFV-CVS CALIBRATION CONFIGURATION

(6) Vary the flow restrictor and make at least 8 readings across the critical flow range of the venturi.

(7) Data analysis. The data recorded during the calibration are to be used in the following calculations:

(i) The air flow rate, Q_s , at each test point is calculated in standard cubic feet per minute from the flow meter data using the manufacturer's prescribed method.

(ii) Calculate values of the calibration coefficient for each test point:

$$K_v = \frac{Q_s \sqrt{T_v}}{P_v}$$

Where:

Q_s = Flow rate in standard cubic feet per minute, standard conditions are 68°F, 29.92 in. Hg (20°C, 101.3 kPa).

T_v = Temperature at venturi inlet, R(K).

P_v = Pressure at venturi inlet, mm Hg (kPa)
 $= P_B - \text{PPI (SP. GR./13.57)}$.
for SI units $P_v = P_B - \text{PPI}$

Where:

PPI = Venturi inlet pressure depression, in. fluid (kPa).

SP. GR. = Specific gravity of manometer fluid, relative to water.

(iii) Plot K_v as a function of venturi inlet pressure. For sonic flow, K_v will have a relatively constant value. As pressure decreases (vacuum increases), the venturi becomes unchoked and K_v decreases. See Figure 8.

(iv) For a minimum of 8 points in the critical region calculate an average K_v and the standard deviation.

(v) If the standard deviation exceeds 0.3% of the average K_v take corrective action.

(c) CVS System Verification.

The following "gravimetric" technique can be used to verify that the CVS and analytical instruments can accurately measure a mass of gas

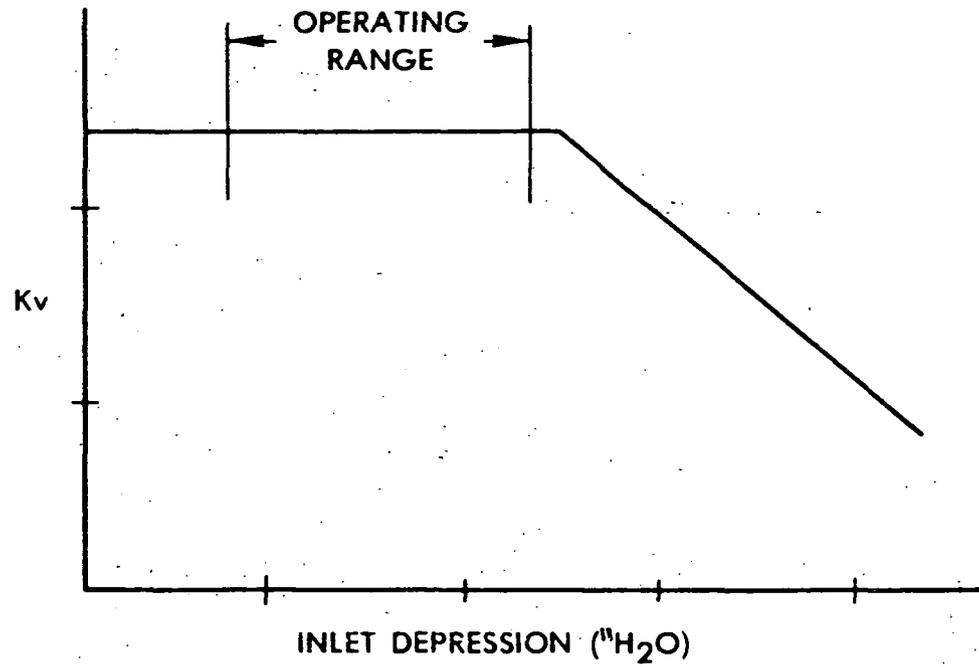


FIGURE 8—SONIC FLOW CHOKING

that has been injected into the system. (Verification can also be accomplished by constant flow metering using critical flow orifice devices.)

(1) Obtain a small cylinder that has been charged with pure propane or carbon monoxide gas (caution--carbon monoxide is poisonous).

(2) Determine a reference cylinder weight to the nearest 0.01 grams.

(3) Operate the CVS in the normal manner and release a quantity of pure propane or carbon monoxide into the system during the sampling period (approximately 5 minutes).

(4) The calculations of section 144 are performed in the normal way except, in the case of propane. The density of propane (17.30 g/ft³/carbon atom (0.6109 kg/m³/carbon atom)) is used in place of the density of exhaust hydrocarbons. In the case of carbon monoxide, the density of 32.97 g/ft³ (1.164 kg/m³) is used.

(5) The gravimetric mass is subtracted from the CVS measured mass and then divided by the gravimetric mass to determine the percent accuracy of the system.

(6) The cause for any discrepancy greater than +2% must be found and corrected.

120 RESERVED

121 HYDROCARBON ANALYZER CALIBRATION.

The FID hydrocarbon analyzer shall receive the following initial and periodic calibration. The HFID shall be operated to a set point +10°F (+ 5.5°C) between 300 and 390°F (149 and 199°C).

(a) Initial and periodic optimization of detector response. Prior to its introduction into service and at least annually thereafter the FID hydrocarbon analyzer shall be adjusted for optimum hydrocarbon response. Alternate methods yielding equivalent results may be used..

(1) Follow the manufacturer's instructions for instrument startup and basic operating adjustment using the appropriate fuel and zero grade air.

(2) Optimize on the most common operating range. Introduce into the analyzer, a propane in air mixture with a propane concentration equal to approximately 90% of the most common operating range.

(3) Select an operating fuel flow rate that will equal to approximately 90% of the most common operating range.

(3) Select an operating fuel flow rate that will give near maximum response and least variation in response with minor fuel flow variations.

(4) To determine the optimum air flow, use the fuel flow setting determined above and vary air flow.

(5) After the optimum flow rates have been determined, they are recorded for future reference.

(b) Initial and periodic calibration. Prior to its introduction into service and monthly thereafter the FID hydrocarbon analyzer shall be calibrated on all normally used instrument ranges. Use the same flow rate as when analyzing samples.

(1) Adjust analyzer to optimize performance.

(2) Zero the hydrocarbon analyzer with zero grade air.

(3) Calibrate on each normally used operating range with propane in air calibration gases having nominal concentrations of 50 and 100% of that range. Additional calibration points may be generated.

122 CARBON MONOXIDE ANALYZER CALIBRATION.

The NDIR carbon monoxide analyzer shall receive the following initial and periodic calibrations:

(a) Initial and periodic interference check. Prior to its introduction into service and annually thereafter the NDIR carbon monoxide analyzer shall be checked for response to water vapor and CO₂:

(1) Follow the manufacturer's instructions for instrument startup and operation. Adjust the analyzer to optimize performance on the most sensitive range.

(2) Zero the carbon monoxide analyzer with either zero grade air or zero grade nitrogen.

(3) Bubble a mixture of 3% CO₂ in N₂ through water at room temperature and record analyzer response.

(4) An analyzer response of more than 1% of full scale for ranges above 300 ppm full scale or of more than 3 ppm on ranges below 300 ppm full scale will require corrective action. (Use of conditioning columns is one form of corrective action which may be taken.)

(b) Initial and periodic calibration. Prior to its introduction into service and monthly thereafter the NDIR carbon monoxide analyzer shall be calibrated.

(1) Adjust the analyzer to optimize performance.

(2) Zero the carbon monoxide analyzer with either zero grade air or zero grade nitrogen.

(3) Calibrate on each normally used operating range with carbon monoxide in N_2 calibration gases having nominal concentrations of 15, 30, 45, 60, 75 and 90% of that range. For each range calibrated, if the deviation from a least-squares best-fit straight line is 2% or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds 2% at any point, the best-fit non-linear equation which represents the data to within 2% of each test point shall be used to determine concentration.

123 OXIDES OF NITROGEN ANALYZER CALIBRATION.

The chemiluminescent oxides of nitrogen analyzer shall receive the following initial and periodic calibration.

(a) Prior to its introduction into service and weekly thereafter the chemiluminescent oxides of nitrogen analyzer shall be checked for NO_2 to NO converter efficiency. Figure 9 is a reference for the following steps:

(1) Follow the manufacturer's instructions for instrument startup and operation. Adjust the analyzer to optimize performance.

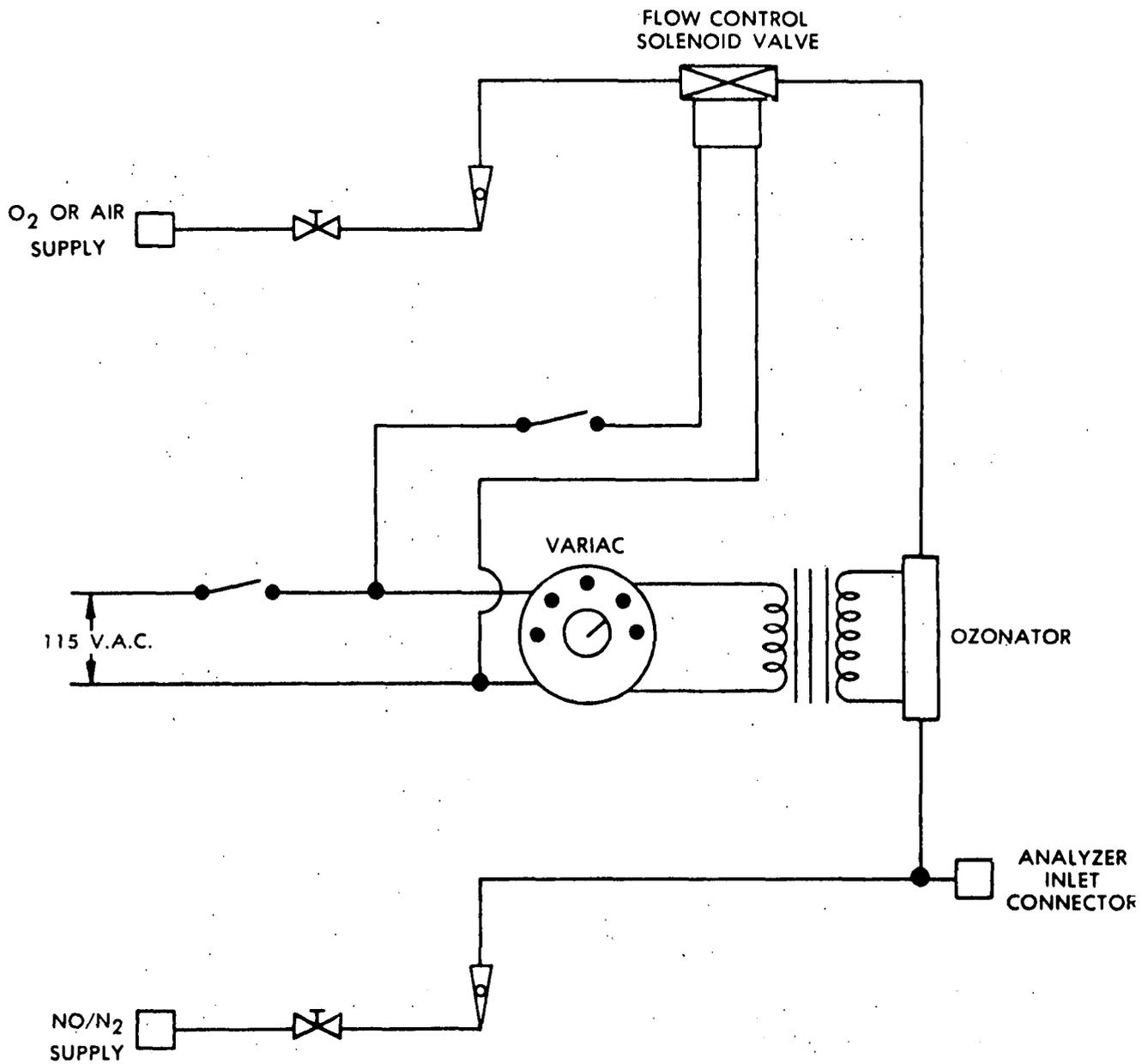
(2) Zero the oxides of nitrogen analyzer with zero grade air or zero grade nitrogen.

(3) Connect the outlet of the NO_x generator to the sample inlet of the oxides of nitrogen analyzer which has been set to the most common operating range.

(4) Introduce into the NO_x generator analyzer-system an NO in nitrogen (N_2) mixture with a NO concentration equal to approximately 80% of the most common operating range. The NO_2 content of the gas mixture shall be less than 5% of the NO concentration.

(5) With the oxides of nitrogen analyzer in the NO mode, record the concentration of NO indicated by the analyzer.

(6) Turn on the NO_x generator O_2 (or air) supply and adjust the O_2 (or air) flow rate so that the NO indicated by the analyzer is about 10% less than indicated in step 5. Record the concentration of NO in this $NO + O_2$ mixture.



(SEE FIG 3 FOR SYMBOL LEGEND)
 FIGURE 9—NO_x CONVERTER EFFICIENCY DETECTOR

(7) Switch the NOx generator to the generation mode and adjust the generation rate so that the NO measured on the analyzer is 20% of that measured in step 5. There must be at least 10% unreacted NO at this point. Record the concentration of residual NO.

(8) Switch the oxides of nitrogen analyzer to the NOx mode and measure total NOx. Record this value.

(9) Switch off the NOx generation but maintain gas flow through the system. The oxides of nitrogen analyzer will indicate the NOx in the NO + O₂ mixture. Record this value.

(10) Turn off the NOx generator O₂ (or air) supply. The analyzer will now indicate the NOx in the original NO in N₂ mixture. This value should be no more than 5% above the value indicated in step 4.

(11) Calculate the efficiency of the NOx converter by substituting the concentrations obtained into the following equation:

$$\% \text{ Eff.} = \left[1 + \frac{a - b}{c - d} \right] \times 100$$

where a = concentration obtained in step 8

b = concentration obtained in step 9

c = concentration obtained in step 6

d = concentration obtained in step 7

If converter efficiency is not greater than 90% corrective action will be required.

(b) Initial and periodic calibration. Prior to its introduction into service and monthly thereafter the chemiluminescent oxides of nitrogen analyzer shall be calibrated on all normally used instrument ranges. Use the same flow rate as when analyzing samples. Proceed as follows:

(1) Adjust analyzer to optimize performance.

(2) Zero the oxides of nitrogen analyzer with zero grade air or zero grade nitrogen.

(3) Calibrate on each normally used operating range with NO in N₂ calibration gases with nominal concentrations of 50 and 100% of that range. Additional calibration points may be generated.

124 CARBON DIOXIDE ANALYZER CALIBRATION.

Prior to its introduction into service and monthly thereafter the NDIR carbon dioxide analyzer shall be calibrated:

(a) Follow the manufacturer's instructions for instrument startup and operation. Adjust the analyzer to optimize performance.

(b) Zero the carbon dioxide analyzer with either zero grade air or zero grade nitrogen.

(c) Calibrate on each normally used operating range with carbon dioxide in N₂ calibration gases with nominal concentrations of 15, 30, 45, 60, 75 and 90% of that range. Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is 2% or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds 2% at any point, the best-fit non-linear equation which represents the data to within 2% of each test point shall be used to determine concentration.

125 RESERVED

126 CALIBRATION OF OTHER EQUIPMENT.

Other test equipment used for testing shall be calibrated as often as required by the manufacturer or as necessary according to good practice.

127 TEST PROCEDURES, OVERVIEW.

(a) The overall test consists of prescribed sequences of fueling, parking and operating conditions. Vehicles are either tested for only exhaust emissions or are tested for exhaust and evaporative emissions. The evaporative portion of the test procedure occurs before and after the exhaust emission test, and, in some cases, during the exhaust emission test.

(b) The exhaust emission test is designed to determine hydrocarbon, carbon monoxide, and oxides of nitrogen mass emissions while simulating an average trip in an urban area of 7.5 miles (12.1 km). The test consists of engine startups and vehicle operation on a chassis dynamometer, through a specified driving schedule. A proportional part of the diluted exhaust emissions is collected continuously for subsequent analysis, using a constant volume (variable dilution) sampler. (Diesel dilute exhaust is continuously analyzed for hydrocarbons using a heated sample line and analyzer).

(c) The evaporative emission test (gasoline fueled vehicles only) is designed to determine hydrocarbon evaporative emissions as a consequence of diurnal temperature fluctuation, urban driving, and hot soaks during parking. It is associated with a series of events representative of a motor vehicle's operation, which result in hydrocarbon vapor losses. The test procedure is designed to measure:

(1) Diurnal breathing losses resulting from daily temperature changes, measured by the enclosure technique;

(2) Running losses from suspected sources (if indicated by engineering analysis or vehicle inspection) resulting from a simulated trip on a chassis dynamometer, measured by carbon traps; and

(3) Hot soak losses which result when the vehicle is parked and the hot engine is turned off, measured by the enclosure technique.

(d) Except in cases of component malfunction or failure, all emission control systems installed on or incorporated in a new motor vehicle shall be functioning during all procedures in this Recommended Practice.

128 TRANSMISSIONS.

(a) All test conditions shall be run with automatic and automatic stick shift transmissions in "Drive" (highest gear); manual transmissions shall be run in highest gear, except as noted. Automatic stick-shift transmissions may be shifted as manual transmissions if requested by the manufacturer.

(b) Cars equipped with free-wheeling or overdrive units shall be tested with these units locked out of operation.

(c) Idle modes shall be run with automatic transmissions in "Drive" and the wheels braked, manual transmissions shall be in gear with the clutch disengaged; except first idle, see sections 136 and 137.

(d) The vehicle shall be driven with minimum accelerator pedal movement to maintain the desired speed.

(e) Acceleration modes shall be driven smoothly. Automatic transmissions shall shift automatically through the normal sequence of gears; manual transmissions shall be shifted as recommended by the manufacturer with the operator releasing the accelerator pedal during each shift and accomplishing the shift with minimum time. If the vehicle cannot accelerate at the specified rate, the vehicle shall be operated with the accelerator pedal fully depressed until the vehicle speed reaches the value prescribed for that time in the driving schedule.

(f) The deceleration modes shall be run in gear using brakes or accelerator pedal as necessary to maintain the desired speed. Manual transmission vehicles shall have the clutch engaged and shall not change gears from the previous mode. For those modes which decelerate to zero, manual transmission clutches shall be depressed when the speed drops below 15 mph (24.14 km/h), when engine roughness is evident, or when engine stalling is imminent.

(g) Manual transmissions will be down shifted at the beginning of or during a power mode if recommended by the manufacturer or if the engine obviously is lugging.

(h) If shift speeds are not recommended by the manufacturer, manual transmission vehicles shall be shifted from first to second gear

at 15 mph (24.14 km/h), from second to third gear at 25 mph (40.23 km/h), and, if so equipped, from third to fourth gear at 40 mph (64.37 km/h). Fifth gear, if so equipped, may be used at the manufacturer's option.

(i) If a four- or five- speed manual transmission has a first gear ratio in excess of 5:1, follow the procedure for three- or four-speed vehicles as if the first gear did not exist.

129 ROAD LOAD POWER AND INERTIA WEIGHT DETERMINATION.

(a) Flywheels, electrical or other means of simulating inertia as shown in the following table shall be used. If the equivalent inertia specified is not available on the dynamometer being used, the next higher equivalent inertia (not to exceed 250 lbs) available shall be used.

| Loaded vehicle weight (pounds) | Equivalent inertia weight (pounds) | Road load power at 50 mph (horsepower) |
|-----------------------------------|---|---|
| Up to 1,125----- | 1,000 | 5.9 |
| 1,126 to 1,375----- | 1,250 | 6.5 |
| 1,376 to 1,625----- | 1,500 | 7.1 |
| 1,626 to 1,875----- | 1,750 | 7.7 |
| 1,876 to 2,125----- | 2,000 | 8.3 |
| 2,126 to 2,375----- | 2,250 | 8.8 |
| 2,376 to 2,625----- | 2,500 | 9.4 |
| 2,626 to 2,875----- | 2,750 | 9.9 |
| 2,876 to 3,250----- | 3,000 | 10.3 |
| 3,251 to 3,750----- | 3,500 | 11.2 |
| 3,751 to 4,250----- | 4,000 | 12.0 |
| 4,251 to 4,750----- | 4,500 | 12.7 |
| 4,751 to 5,250----- | 5,000 | 13.4 |
| 5,251 to 5,750----- | 5,500 | 13.9 |
| 5,751 to above----- | 5,500 | 14.4 |

(b) Power absorption unit adjustment.

(1) The power absorption unit shall be adjusted to reproduce road load power at 50 mph true speed. The indicated road load power setting shall take into account the dynamometer friction. The relationship between road load (absorbed) power and indicated road load power for a particular dynamometer shall be determined by the procedure outlined in section 118 or other suitable means.

(2) The road load power listed in the table above shall be used or the vehicle manufacturer may determine the road load power by an alternate procedure, or the vehicle manufacturer may determine the road load power by the following procedure and request its use:

(i) Gasoline fueled vehicles.

(A) Measuring the absolute manifold pressure of a representative vehicle, of the same equivalent inertia weight class, when operated on a level road under balanced wind conditions at a true speed of 50 mph (80 km/h), and

(B) Noting the dynamometer indicated road load horsepower setting required to reproduce that manifold pressure when the same vehicle is operated on the dynamometer at a true speed of 50 mph. The tests on the road and on the dynamometer shall be performed with the same vehicle ambient absolute pressure (usually barometric), i.e., within ± 5 mm Hg (± 0.7 kPa).

(C) The road load power shall be determined according to the procedure outlined in section 118 and adjusted according to the following if applicable.

(ii) Diesel vehicles.

(A) Measuring the fuel flow rate of a representative vehicle of the same equivalent inertia weight class, when operated on a level road under balanced wind conditions at a true speed of 50 mph, and

(B) Noting the dynamometer indicated road load horsepower setting required to reproduce that fuel flow rate when the same vehicle is operated on the dynamometer at a true speed of 50 mph (80 km/h). The tests on the road and on the dynamometer shall be performed with the same vehicle ambient absolute pressure (usually barometric), i.e. within ± 5 mm Hg (± 0.7 kPa):

(C) The road load power shall be determined according to the procedure outlined in section 118 and adjusted according to the following if applicable.

(3) Where it is expected that more than 33 percent of the vehicles in an engine family will be equipped with air conditioning, the road load power listed above or as determined in paragraph (b)(2) of this section shall be increased by 10 percent for testing all test vehicles representing such an engine family if those vehicles are intended to be offered with air conditioning in production.

130 TEST SEQUENCE, GENERAL REQUIREMENTS.

The test sequence shown in Figure 10 shows the steps encountered as the test vehicle undergoes the procedures subsequently described to determine conformity with the standards set forth. Ambient temperature levels encountered by the test vehicle throughout the test sequence shall not be less than 68°F (20°C) nor more than 86°F (30°C). The vehicle shall be approximately level during all phases of the test sequence to prevent abnormal fuel distribution.

131 VEHICLE PREPARATION.

(a) For gasoline fueled vehicles prepare the fuel tank(s) for recording the temperature of the prescribed test fuel at the approximate mid-volume of the fuel.

(b) Provide additional fittings and adapters, as required, to accommodate a fuel drain at the lowest point possible in the tank(s) as installed on the vehicle.

132 VEHICLE PRECONDITIONING.

(a) The vehicle shall be moved to the test area and the following operations performed:

(1) The fuel tank(s) shall be drained through the provided fuel tank(s) drain(s) and filled to the prescribed "tank fuel volume" with the specified test fuel, section 111. For the above operations the evaporative emission control system shall neither be abnormally purged nor abnormally loaded.

(2) Within one hour of being fueled the vehicle shall be placed, either by being driven or pushed, on a dynamometer and operated through one Urban Dynamometer Driving Schedule test procedure, see section 115 and Appendix I of the Federal Register. A gasoline fueled test vehicle may not be used to set dynamometer horsepower.

(3) For those unusual circumstances where additional preconditioning is desired to insure that the evaporative emission control system is stabilized, such preconditioning shall consist of an initial one hour minimum soak and, one, two or three driving cycles of the UDDS, as described in (a)(2), each followed by a soak of at least one hour with engine off, engine compartment cover closed and cooling fan off. The vehicle may be driven off the dynamometer following each UDDS for the soak period.

(b) Within five minutes of completion of preconditioning the vehicle shall be driven off the dynamometer and parked. The vehicle shall be stored for not less than 12 hours nor for more than 36 hours (except diesel fueled vehicles which have no maximum time limitation)

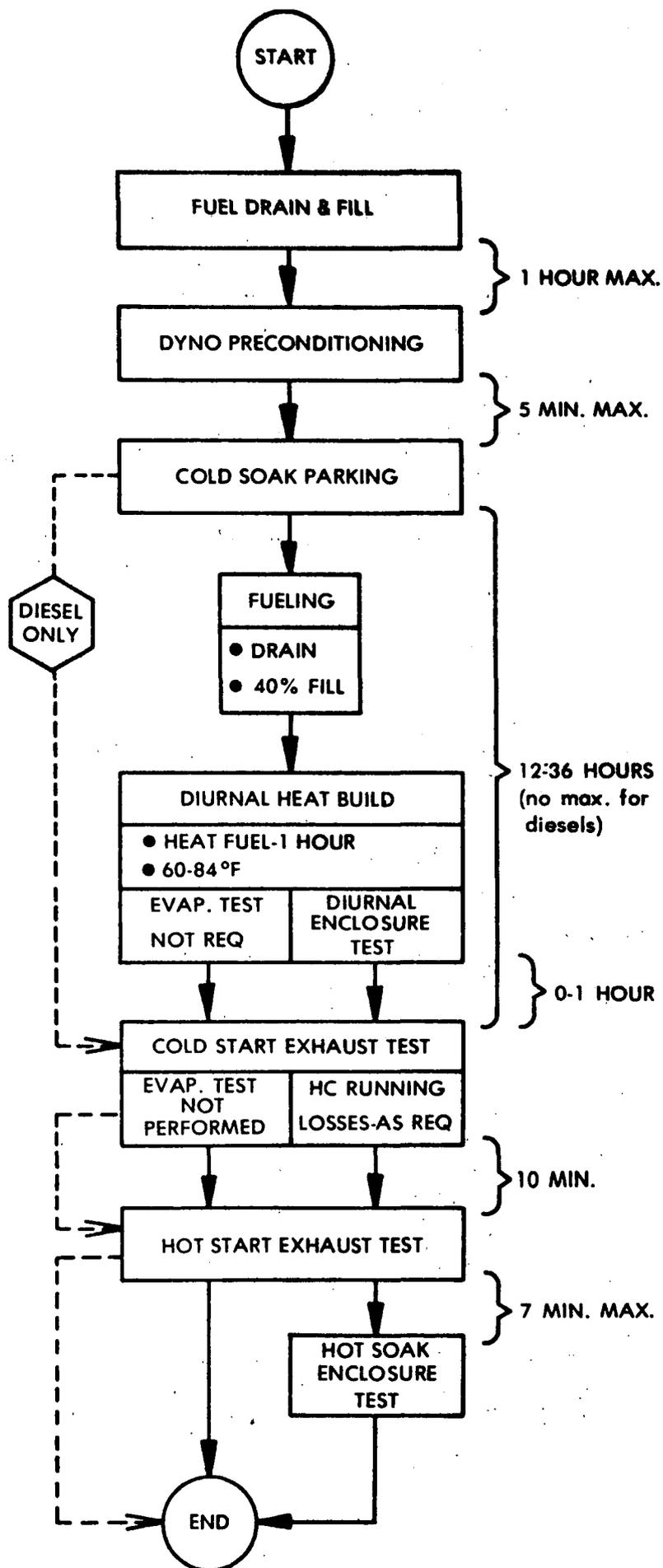


FIGURE 10 TEST SEQUENCE

prior to the cold start exhaust test. (Gasoline fueled vehicles undergo a one hour diurnal heat build prior to the cold start exhaust test. A wait of up to one hour is permitted between the end of the diurnal heat build and the beginning of the cold start exhaust test. See section 130 and Figure 10.)

(c) Vehicles to be tested for evaporative emissions shall be processed in accordance with procedures in sections 133 through 138. Vehicles to be tested for exhaust emissions only shall be processed according to sections 133 through 137.

133 DIURNAL BREATHING LOSS TEST.

(a)(1) Following vehicle preparation and vehicle preconditioning procedures described in section 131 and section 132 the test vehicle shall be allowed to soak for a period of not less than 12 or more than 36 hours prior to the exhaust emission test. The diurnal test shall start not less than 10 or more than 35 hours after the end of the preconditioning procedure. The start of the exhaust test shall follow the end of the diurnal test within one hour.

(2) Gasoline fueled vehicles to be tested for exhaust emissions only, shall undergo the diurnal heat build. Since no evaporative measurements are necessary, an evaporative enclosure is not required.

(b) The evaporative emission enclosure shall be purged for several minutes immediately prior to the test.

NOTE: If at anytime the hydrocarbon concentration exceeds 15,000 ppm C the enclosure should be immediately purged. This concentration provides a 4:1 safety factor against the lean flammability limit.

(c) The FID hydrocarbon analyzer shall be zeroed and spanned immediately prior to the test.

(d) If not already on, the evaporative enclosure mixing fan shall be turned on at this time.

(e) Immediately prior to the diurnal breathing loss test, the fuel tank(s) of the prepared vehicle shall be drained and recharged with the specified test fuel, section 113, to the prescribed "tank fuel volume," defined in the Federal Register. The temperature of the fuel prior to its delivery to the fuel tank shall be between 50 and 60°F (10 and 16°C). The fuel tank cap(s) is not installed until the diurnal heat build begins.

(f) The test vehicle, with the engine shut off, shall be moved into the evaporative emission enclosure, the test vehicle windows and luggage compartments shall be opened, the fuel tank temperature sensor shall be connected to the temperature recording system, and, if required,

the heat source shall be properly positioned with respect to the fuel tank(s) and/or connected to the temperature controller.

(g) The temperature recording system shall be started.

(h) The fuel may be artificially heated to the starting diurnal temperature.

(i) When the fuel temperature recording system reaches at least 58°F (14°C), immediately:

(1) Install fuel tank cap(s).

(2) Turn off purge blowers, if not already off at this time.

(3) Close and seal enclosure doors.

(j) When the fuel temperature recording system reaches $60 \pm 2^\circ\text{F}$ ($16 \pm 1.1^\circ\text{C}$), immediately:

(1) Analyze enclosure atmosphere for hydrocarbons and record. This is the initial (time = 0 minutes) hydrocarbon concentration, C_{HCi} , section 143.

(2) Start diurnal heat build and record time. This commences the 60 ± 2 minute test period.

(k) The fuel shall be heated in such a way that its temperature change conforms to the following function to within $\pm 3^\circ\text{F}$ ($\pm 1.6^\circ\text{C}$):

$$F = T_0 + 0.4t$$
$$\text{for SI units, } C = T_0 + (2/9)t$$

Where:

F = fuel temperature, °F
C = fuel temperature, °C
t = time since beginning of test, minutes.
 T_0 = initial temperature

After 60 ± 2 minutes of heating, the fuel temperature rise shall be $24 \pm 1^\circ\text{F}$ ($\pm 0.5^\circ\text{C}$).

(1) The FID hydrocarbon analyzer shall be zeroed and spanned immediately prior to the end of the diurnal test.

(m) The end of the diurnal breathing loss test occurs 60 ± 2 minutes after the heat build begins, paragraph (j)(2). Analyze the enclosure atmosphere for hydrocarbons and record. This is the final (time = 60 minutes) hydrocarbon concentration, C_{HCf} , section 143. The time (or elapsed time) of this analysis shall be recorded.

(n) The heat source shall be turned off and the enclosure doors unsealed and opened.

(o) The heat source shall be moved away from the vehicle, if required, and/or disconnected from the temperature controller, the fuel tank temperature sensor shall be disconnected from the temperature recording system, the test vehicle windows and luggage compartments may be closed and the test vehicle, with the engine shut off, shall be removed from the evaporative emission enclosure.

(p) 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 paragraph (k) of this section. All other tanks shall be designated as auxiliary tanks and shall undergo a similar heat build such that the fuel temperature shall be within 3°F (1.6°C) of the primary tank.

134 RUNNING LOSS TEST.

(a) If an engineering analysis or vehicle inspection indicates the possibility of evaporative emissions during vehicle operation, evaporative emission running loss measurements shall be made during the cold transient and stabilized portion of the exhaust emission test. Since running loss measurements cannot be made in the enclosure, the equipment described in the Federal Register shall be used to collect these emissions.

(1) The procedure in section 135 shall be followed.

(2) Prior to the initiation of the cold start exhaust emission test, the vapor loss measurement system shall be connected to all suspected sources of running loss evaporative emissions.

(3) The cold start transient and stabilized exhaust emission test portions shall be conducted according to the procedures of sections 135 through 137.

(4) Within one minute after the end of the stabilized exhaust emission test, the vapor loss measurement system shall be disconnected from the vehicle and the inlets and outlets sealed.

(5) Within one hour from the end of the running loss measurement, weigh the vapor collection traps.

135 DYNAMOMETER PROCEDURE.

(a) The dynamometer run consists of two tests, a "cold" start test after a minimum 12-hour and a maximum 36 hour soak according to the provisions of section 132 and section 133 and a "hot" start test fol-

lowing the "cold" start test by 10 minutes. Engine startup (with all accessories turned off), operation over the driving schedule, and engine shutdown make a complete cold start test. Engine startup and operation over the first 505 seconds of the driving schedule complete the hot start test. The exhaust emissions are diluted with ambient air and a continuously proportional sample is collected for analysis during each phase. The composite samples collected in bags are analyzed for hydrocarbons (except diesel hydrocarbons which are analyzed continuously), carbon monoxide, carbon dioxide, and oxides of nitrogen. A parallel sample of the dilution air is similarly analyzed for hydrocarbon, carbon monoxide, carbon dioxide, and oxides of nitrogen.

(b) During dynamometer operation, a fixed speed cooling fan shall be positioned so as to direct cooling air to the vehicle in an appropriate manner with the engine compartment cover open. In the case of vehicles with front engine compartments, the fan shall be squarely positioned within 12 inches of the vehicle. In the case of vehicles with rear engine compartments (or if special designs make the above impractical), the cooling fan shall be placed in a position to provide sufficient air to maintain vehicle cooling. The fan capacity shall normally not exceed 5,300 cfm (2.50 m³/s). If, however, the manufacturer can show that during field operation the vehicle receives additional cooling, and that such additional cooling is needed to provide a representative test, the fan capacity may be increased or additional fans used.

(c) The vehicle speed as measured from the dynamometer rolls shall be used.

(d) Practice runs over the prescribed driving schedule may be performed at test points, provided an emission sample is not taken, for the purpose of finding the minimum throttle action to maintain the proper speed-time relationship, or to permit sampling system adjustments.

NOTE: When using two-roll dynamometers a truer speed-time trace may be obtained by minimizing the rocking of the vehicle in the rolls. The rocking of the vehicle changes the tire rolling radius on each roll. This rocking may be minimized by restraining the vehicle horizontally (or nearly so) by using a cable and winch.

(e) The drive wheel tires may be inflated up to a gauge pressure of 45 psi (310 kPa) in order to prevent tire damage. The drive wheel tire pressure shall be reported with the test results.

(f) If the dynamometer has not been operated during the 2 hour period immediately preceding the test it shall be warmed up for 15 minutes by operating at 30 mph (48 km/h) using a non-test vehicle or as recommended by the dynamometer manufacturer.

(g) If the dynamometer horsepower must be adjusted manually, it shall be set within 1 hour prior to the exhaust emissions test phase. The test vehicle shall not be used to make this adjustment. Dynamometers using automatic control of preselectable power settings may be set anytime prior to the beginning of the emissions test.

136 ENGINE STARTING AND RESTARTING.

(a) Gasoline fueled vehicles. Paragraph (a) applies to gasoline fueled vehicles.

(1) The engine shall be started according to the manufacturer's recommended starting procedures. The initial 20 second idle period shall begin when the engine starts.

(2) Choke operation:

(i) Vehicles equipped with automatic chokes shall be operated according to the manufacturer's operating instructions or owner's manual, including choke setting and "kick-down" from cold fast idle. The transmission shall be placed in gear 15 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.

(ii) Vehicles equipped with manual chokes shall be operated according to the manufacturer's operating instructions or owners manual.

(3) The operator may use the choke, accelerator pedal, etc. where necessary to keep the engine running.

(4) If the manufacturer's operating instructions or owner's manual does not specify a warm engine starting procedure, the engine (automatic and manual choke engines) shall be started by depressing the accelerator pedal about half way and cranking the engine until it starts.

(b) Diesel fueled vehicles. The engine shall be started according to the manufacturer's recommended starting procedures. The initial 20-second-idle period shall begin when the engine starts. The transmission shall be placed in gear 15 seconds after the engine is started. If necessary, braking may be employed to keep the drive wheels from turning.

(c) If the vehicle does not start after 10 seconds of cranking, cranking shall cease and the reason for failure to start shall be determined. The gas flow measuring device (or revolution counter) on the constant volume sampler (and the hydrocarbon integrator when testing diesel vehicles, see section 137, Dynamometer test runs) shall be turned off and the sample selector valves placed in the "standby" position during this diagnostic period. In addition, either the CVS should be turned off or the exhaust tube disconnected from the tailpipe during the diagnostic period.

(1) If failure to start is an operational error, the vehicle shall be rescheduled for testing from a cold start. If failure to start is caused by vehicle malfunction, corrective action of less than 30 minutes duration may be taken and the test continued. The sampling system shall be reactivated at the same time cranking is started. When the engine starts, the driving schedule timing sequence shall begin. If failure to start is caused by vehicle malfunction and the vehicle cannot be started, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken, and the vehicle rescheduled for test. The reason for the malfunction (if determined) and the corrective action taken shall be reported.

(d) If the engine "false starts", the operator shall repeat the recommended starting procedure (such as resetting the choke, etc.)

(e) Stalling:

(1) If the engine stalls during an idle period, the engine shall be restarted immediately and the test continued. If the engine cannot be started soon enough to allow the vehicle to follow the next acceleration as prescribed, the driving schedule indicator shall be stopped. When the vehicle restarts, the driving schedule indicator shall be reactivated.

(2) If the engine stalls during some operating mode other than idle, the driving schedule indicator shall be stopped, the vehicle shall then be restarted and accelerated to the speed required at that point in the driving schedule and the test continued. During acceleration to this point, shifting shall be performed in accordance with section 128.

(3) If the vehicle will not restart within 1 minute, the test shall be voided, the vehicle removed from the dynamometer, corrective action taken, and the vehicle rescheduled for test. The reason for the malfunction (if determined) and the corrective action taken shall be reported.

137 DYNAMOMETER TEST RUNS.

(a) The vehicle shall be allowed to stand with the engine turned off for a period of not less than 12 hours or more than 36 hours before the cold start exhaust emission test. The cold start exhaust test shall follow the diurnal breathing loss test by not more than 1 hour. The vehicle shall be stored prior to the emission test in such a manner that precipitation (e.g. rain or dew) does not occur on the vehicle. The complete dynamometer test consists of a cold start drive of 7.5 miles (12.1 km) and simulates a hot start drive of 7.5 miles (12.1 km). The vehicle is allowed to stand on the dynamometer during the 10 minute time period between the cold and hot start tests. The cold start test is divided into two periods. The first period, representing the cold start

"transient" phase, terminates at the end of the deceleration which is scheduled to occur at 505 seconds of the driving schedule. The second period, representing the "stabilized" phase, consists of the remainder of the driving schedule including engine shutdown. The hot start test similarly consists of two periods. The period, representing the hot start "transient" phase, terminates at the same point in the driving schedule as the first period of the cold start test. The second period of the hot start test, "stabilized" phase, is assumed to be identical to the second period of the cold start test. Therefore, the hot start test terminates after the first period (505 seconds) is run.

(b) The following steps shall be taken for each test:

(1) Place drive wheels of vehicle on dynamometer without starting engine.

(2) Open the vehicle engine compartment cover and position the cooling fan.

(3) With the sample selector valves in the "standby" position connect evacuated sample collection bags to the two dilute exhaust and two dilution air sample collection systems.

(4) Start the Constant Volume Sampler (if not already on), the sample pumps, the temperature recorder, the vehicle cooling fan and the heated hydrocarbon analysis recorder (diesel only). (The heat exchanger of the constant volume sampler, if used, diesel hydrocarbon analyzer continuous sample line and filter (if applicable) should be preheated to their respective operating temperatures before the test begins.)

(5) Adjust the sample flow rates to the desired flow rate (minimum of 10 cfh, $0.28 \text{ m}^3/\text{hr}$) and set the gas flow measuring devices to zero.

NOTE: CFV-CVS sample flowrate is fixed by the venturi design.

(6) Attach the flexible exhaust tube to the vehicle tailpipe(s).

(7) Start the gas flow measuring device, position the sample selector valves to direct the sample flow into the "transient" exhaust sample bag and the "transient" dilution air sample bag, (turn on the diesel hydrocarbon analyzer system integrator and mark the recorder chart, if applicable) and start cranking the engine.

(8) Fifteen seconds after the engine starts, place the transmission in gear.

(9) Twenty seconds after the engine starts, begin the initial vehicle acceleration of the driving schedule.

(10) Operate the vehicle according to the dynamometer driving schedule (section 115).

(11) At the end of the deceleration which is scheduled to occur at 505 seconds, simultaneously switch the sample flows from the "transient" bags to the "stabilized" bags, switch off gas flow measuring device No. 1 (and the diesel hydrocarbon integrator No. 1, mark the diesel hydrocarbon recorder chart) and start gas flow measuring device No. 2 (and diesel hydrocarbon integrator No. 2). As soon as possible, and in no case longer than 20 minutes after the end of this portion of the test, transfer the "transient" exhaust and dilution air sample bags, to the analytical system and process the samples according to section 140.

(12) Turn the engine off 2 seconds after the end of the last deceleration (at 1,369 seconds).

(13) Five seconds after the engine stops running, simultaneously turn off gas flow measuring device No. 2 (and the diesel hydrocarbon integrator No. 2, mark the hydrocarbon recorder chart, if applicable) and position the sample selector valves to the "standby" position. As soon as possible, and in no case longer than 20 minutes after the end of this portion of the test, transfer the "stabilized" exhaust and dilution air sample bags, to the analytical system and process the samples according to section 140.

(14) Immediately after the end of the sample period turn off the cooling fan and close the engine compartment cover.

(15) Turn off the CVS or disconnect the exhaust tube from the tailpipe of the vehicle.

(16) Repeat the steps in paragraph (b)(2) through (10) of this section for the hot start test, except only one evacuated sample bag is required for sampling exhaust gas and one for dilution air. The step in paragraph (b)(7) of this section shall begin between 9 and 11 minutes after the end of the sample period for the cold start test.

(17) At the end of the deceleration which is scheduled to occur at 505 seconds, simultaneously turn off gas flow measuring device No. 1 (and diesel hydrocarbon integrator No. 1, mark the diesel hydrocarbon recorder chart, if applicable) and position the sample selector valve to the "standby" position. (Engine shutdown is not part of the hot start test sample period.)

(18) As soon as possible, and in no case longer than 20 minutes after the end of this portion of the test transfer the hot start "transient" exhaust and dilution air sample bags, to the analytical system and process the samples according to section 135.

(19) Disconnect the exhaust tube from the vehicle tailpipe(s) and drive vehicle from dynamometer.

(20) The constant volume sampler may be turned off, if desired.

(21) Vehicles to be tested for evaporative emissions will proceed according to section 138. For all others this completes the test sequence.

138 HOT SOAK TEST.

The hot soak evaporative emission test shall be conducted immediately following the hot transient exhaust emission test.

(a) Prior to the completion of the hot start transient exhaust emission sampling period, the evaporative emission enclosure shall be purged for several minutes.

(b) The FID hydrocarbon analyzer shall be zeroed and spanned immediately prior to the test.

(c) If not already on, the evaporative enclosure mixing fan shall be turned on at this time.

(d) Upon completion of the hot transient exhaust emission sampling period, the vehicle engine compartment cover shall be closed, the cooling fan shall be moved, the vehicle shall be disconnected from the dynamometer and exhaust sampling system, and then driven at minimum throttle to the vehicle entrance of the enclosure.

(e) The vehicle's engine must be stopped before any part of the vehicle enters the enclosure. The vehicle may be pushed or coasted into the enclosure.

(f) The test vehicle windows and luggage compartments shall be opened, if not already open.

(g) The temperature recording system shall be started and the time of engine shut off shall be noted on the evaporative emission hydrocarbon data recording system.

(h) The enclosure doors shall be closed and sealed within two minutes of engine shutdown and within seven minutes after the end of the exhaust test.

(i) The 60 ± 0.5 minute hot soak begins when the enclosure doors are sealed. The enclosure atmosphere shall be analyzed and recorded. This is the initial (time = 0 minutes) hydrocarbon concentration, C_{HCi} , for use in calculating evaporative losses, see section 143.

(j) The test vehicle shall be permitted to soak for a period of at least one hour in the enclosure.

(k) The FID hydrocarbon analyzer shall be zeroed and spanned immediately prior to the end of the test.

(1) At the end of the 60 ± 0.5 minute test period, again analyze the enclosure atmosphere and record time. This is the final (time = 60 minutes) hydrocarbon concentration, C_{HCf} , for use in calculating evaporative losses, see section 143. This operation completes the evaporative emission measurement procedure.

139 RESERVED

140 EXHAUST SAMPLE ANALYSIS.

The following sequence of operations shall be performed in conjunction with each series of measurements:

(a) Zero the analyzers and obtain a stable zero reading. Recheck after tests.

(b) Introduce span gases and set instrument gains. In order to avoid corrections, span and calibrate at the same flow rates used to analyze the test sample. Span gases should have concentrations equal to 75 to 100 percent of full scale. If gain has shifted significantly on the analyzers, check the calibrations. Show actual concentrations on chart.

(c) Check zeros; repeat the procedure in paragraphs (a) and (b) of this section if required.

(d) Check flowrates and pressures.

(e) Measure HC, CO, CO₂ and NO_x concentrations of samples.

(f) For diesel vehicles, continuously record (integrate electronically if desired) dilute hydrocarbon emission levels during test. Background samples are collected in sample bags and analyzed as above.

(g) Check zero and span points. If difference is greater than 2% of full scale, repeat the procedure in paragraphs (a) through (f).

141 RESERVED

142 RECORDS REQUIRED.

The following information shall be recorded with respect to each test:

(a) Test number.

(b) System or device tested (brief description).

(c) Date and time of day for each part of the test schedule.

(d) Instrument operator.

(e) Driver or operator.

(f) Vehicle: Make - Vehicle identification number - Model year - Transmission type - Odometer reading - Engine displacement - Engine family - Evap. family - Idle rpm - Fuel system (fuel injection, nominal fuel tank(s) capacity, fuel tank(s) location, number of carburetors, number of carburetor barrels) - Inertia loading - Actual curb weight recorded at 0 miles - Actual road load at 50 mph (80 km/h) and drive wheel tire pressure, as applicable.

(g) Indicated road load power absorption at 50 mph (80 km/h) and dynamometer serial number. As an alternative to recording the dynamometer serial number, a reference to a vehicle test cell number may be used, provided the test cell records show the pertinent information.

(h) All pertinent instrument information such as tuning - gain - serial number - detector number - range. As an alternative, a reference to a vehicle test cell number may be used, provided test cell calibration records show the pertinent instrument information.

(i) Recorder charts: Identify zero, span, exhaust gas, and dilution air sample traces.

(j) Test cell barometric pressure, ambient temperature and humidity.

NOTE: A central laboratory barometer may be used; provided that individual test cell barometric pressures are shown to be within + 0.1 percent of the barometric pressure at the central barometer location.

(k) Fuel temperatures, as prescribed.

(l) Pressure of the mixture of exhaust and dilution air entering the CVS metering device, the pressure increase across the device, and the temperature at the inlet. The temperature may be recorded continuously or digitally to determine temperature variations.

(m) The number of revolutions of the positive displacement pump accumulated during each test phase while exhaust samples are being collected. The number of standard cubic feet metered by a critical flow venturi during each test phase would be the equivalent record for a CFV-CVS.

(n) The humidity of the dilution air.

NOTE: If conditioning columns are not used (see section 122 and section 144) this measurement can be deleted. If the conditioning columns are used and the dilution air is taken from the test cell, the ambient humidity can be used for this measurement.

(o) Temperature set point of the heated sample line and heated hydrocarbon detector temperature control system (for diesel vehicles only).

143 CALCULATIONS; EVAPORATIVE EMISSIONS.

The calculation of the net hydrocarbon mass change in the enclosure is used to determine the diurnal and hot soak mass emissions. The mass is calculated from initial and final hydrocarbon concentrations in ppm carbon, initial and final enclosure ambient temperatures, initial and final barometric pressures, and net enclosure volume using the following equation:

$$M_{HC} = k V_n \times 10^{-4} \left[\frac{C_{HCf} P_{Bf}}{T_f} - \frac{C_{HCi} P_{Bi}}{T_i} \right]$$

Where:

M_{HC} = hydrocarbon mass, g.

C_{HC} = hydrocarbon concentration as ppm carbon.

V_n = net enclosure volume, ft^3 (m^3) as determined by subtracting 50 ft^3 (1.42 m^3) (volume of vehicle with trunk and windows open) from the enclosure volume. A manufacturer may use the measured volume of the vehicle (instead of the nominal 50 ft^3), provided the measured volume is determined and used for all vehicles tested by that manufacturer.

P_B = barometric pressure, in. Hg (kPa).

T = enclosure ambient temperature, R (K).

$k = .208 (12 + H/C)$
for SI units, $k = 1.2 (12 + H/C)$.

Where:

H/C = Hydrogen-carbon ratio.

H/C = 2.33 for diurnal emissions.

H/C = 2.2 for hot soak emissions.

i = indicates initial reading.

f = indicates final reading.

144 CALCULATIONS; EXHAUST EMISSIONS.

The final reported test results shall be computed by use of the following formula:

(a) For light duty vehicles and light duty trucks:

$$Y_{wm} = (0.43 Y_{ct} + 0.57 Y_{ht} + Y_s) / 7.5$$

Where:

Y_{wm} = Weighted mass emissions of each pollutant, i.e., HC, CO, or NOx, in grams per vehicle mile.

Y_{ct} = Mass emissions as calculated from the "transient" phase of the cold start test, in grams per test phase.

Y_{ht} = Mass emissions as calculated from the "transient" phase of the hot start test, in grams per test phase.

Y_s = Mass emissions as calculated from the "stabilized" phase of the cold start test, in grams per test phase.

(b) The mass of each pollutant for each phase of both the cold start test and the hot start test is determined from the following:

(1) Hydrocarbon mass:

$$HC_{mass} = V_{mix} \times \text{Density}_{HC} \times (HC_{conc} / 1,000,000)$$

(2) Oxides of nitrogen mass:

$$NOx_{mass} = V_{mix} \times \text{Density}_{NO_2} \times K_H \times (NOx_{conc} / 1,000,000)$$

(3) Carbon monoxide mass:

$$CO_{mass} = V_{mix} \times \text{Density}_{CO} \times (CO_{conc} / 1,000,000)$$

(4) Carbon dioxide mass:

$$CO_{2mass} = V_{mix} \times \text{Density}_{CO_2} \times (CO_{2conc} / 100)$$

(c) Meaning of symbols:

(1) HC_{mass} = Hydrocarbon emissions, in grams per test phase.

Density_{HC} = Density of hydrocarbons is 16.33 g/ft³ (.5767 kg/m³), assuming an average carbon to hydrogen ratio of 1:1.85, at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

HC_{conc} = Hydrocarbon concentration of the dilute exhaust sample corrected for background, in ppm carbon equivalent, i.e., equivalent propane X 3.

$$HC_{conc} = HC_e - HC_d (1-1/DF)$$

Where:

HC_e = Hydrocarbon concentration of the dilute exhaust sample or, for diesel, average hydrocarbon concentration of the dilute exhaust sample as calculated from the integrated HC traces, in ppm carbon equivalent.

HC_d = Hydrocarbon concentration of the dilution air as measured, in ppm carbon equivalent.

- (2) NOx_{mass} = Oxides of nitrogen emissions, in grams per test phase.

Density_{NO₂} = Density of oxides of nitrogen is 54.16 g/ft³ (1.913 kg/m³), assuming they are in the form of nitrogen dioxide, at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

NOx_{conc} = Oxides of nitrogen concentration of the dilute exhaust sample corrected for background, in ppm.

$$NOx_{conc} = NOx_e - NOx_d (1-1/DF)$$

Where:

NOx_e = Oxides of nitrogen concentration of the dilute exhaust sample as measured, in ppm.

NOx_d = Oxides of nitrogen concentration of the dilute air as measured, in ppm.

- (3) CO_{mass} = Carbon monoxide emissions, in grams per test phase.

Density_{CO} = Density of carbon monoxide is 32.97 g/ft³ (1.164 kg/m³), at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

CO_{conc} = Carbon monoxide concentration of the dilute exhaust sample corrected for background, water vapor, and CO_2 extraction, in ppm.

$$CO_{\text{conc}} = CO_e - CO_d (1-1/DF)$$

Where:

CO_e = Carbon monoxide concentration of the dilute exhaust sample volume corrected for water vapor and carbon dioxide extraction, in ppm. The calculation assumes the carbon to hydrogen ratio of the fuel is 1:1.85.

$$CO_e = (1-0.01925 CO_{2e} - 0.000323 R) CO_{em}$$

Where:

CO_{em} = Carbon monoxide concentration of the dilute exhaust sample as measured, in ppm.

CO_{2e} = Carbon dioxide concentration of the dilute exhaust sample, in percent.

R = Relative humidity of the dilution air, in percent (see section 142(n)).

CO_d = Carbon monoxide concentration of the dilution air corrected for water vapor extraction, in ppm.

$$CO_d = (1-0.000323 R) CO_{dm}$$

Where:

CO_{dm} = Carbon monoxide concentration of the dilution air sample as measured, in ppm.

NOTE: If a CO instrument which meets the criteria specified in section 111 is used and the conditioning column has been deleted, CO_{em} can be substituted directly for CO_e and CO_{dm} can be substituted directly for CO_d .

(4) $CO_{2\text{mass phase}}$ = Carbon dioxide emissions, in grams per test phase.

Density CO_2 = Density of carbon dioxide is 51.85 g/ft³ (1.843 kg/m³), at 68°F (20°C) and 760 mm Hg (101.3 kPa) pressure.

$CO_{2\text{conc exhaust}}$ = Carbon dioxide concentration of the dilute exhaust sample corrected for background, in percent.

$$(5) DF = 13.4 / [CO_2 + (HC_e + CO_e) 10^{-4}]$$

K_H = Humidity correction factor.

$$K_H = 1 / [1 - 0.0047 (H - 75)]$$

$$\text{for SI units} = 1 / [1 - 0.0329 (H - 10.71)]$$

Where:

H = Absolute humidity in grains (grams) of water per pound (kilogram) of dry air.

$$H = [(43.478) R_a \times P_d] / [P_B - (P_d \times R_a / 100)]$$

$$\text{for SI units, } H = [(6.211) R_a \times P_d] / [P_B - (P_d \times R_a / 100)]$$

R_a = Relative humidity of the ambient air, in percent.

P_d = Saturated vapor pressure, in mm Hg (kPa) at the ambient dry bulb temperature.

P_B = Barometric pressure, in mm Hg (kPa).

V_{mix} = Total dilute exhaust volume in cubic feet per test phase corrected to standard conditions (528 R (293 K) and 760 mm Hg (101.3 kPa)).

For PDP-CVS, V_{mix} is:

$$V_{mix} = V_o \times N \frac{(P_B - P_4) (528 R)}{(760 \text{ mm Hg}) (T_p)}$$

$$\text{for SI units, } V_{mix} = V_o \times N \frac{(P_B - P_4) (293.15 K)}{(101.325 \text{ kPa}) (T_p)}$$

Where:

V_o = Volume of gas pumped by the positive displacement pump, in cubic feet (m^3) per revolution. This volume is dependent on the pressure differential across the positive displacement pump.

N = Number of revolutions of the positive displacement pump during the test phase while samples are being collected.

P_B = Barometric pressure, in mm Hg (kPa).

P_4 = Pressure depression below atmospheric measured at the inlet to the positive displacement pump, in mm Hg (kPa).

T_P = Average temperature of dilute exhaust entering positive displacement pump during test, R(K).

(d) Example calculation of mass values of exhaust emissions using positive displacement pump:

(1) For the "transient" phase of the cold start test assume the following: $V = 0.29344 \text{ ft}^3/\text{revolution}$; $N = 10,485$; $R = 48.0\%$; $R_c = 48.2\%$; $P_B = 762 \text{ mm Hg}$; $P_d = 22.225 \text{ mm Hg}$; $P_4 = 70 \text{ mm Hg}$; $T = 570 \text{ R}$; $HC_a = 105.8 \text{ ppm}$, carbon equivalent; $NOx = 11.2 \text{ ppm}$; $CO_{em} = 306.6 \text{ ppm}$; $CO_{2e} = 1.43\%$; $HC_d = 12.1 \text{ ppm}$; $NOx_d = 0.8 \text{ ppm}$; $CO_{dm}^e = 15.3 \text{ ppm}$.

Then:

$$V_{mix} = (0.29344)^3 (10,485) (762 - 70) (528) / (760) (570) = 2595.0 \text{ ft}^3 \text{ per test phase.}$$

$$H = (43.478) (48.2) (22.225) / [762 - (22.225 \times 48.2/100)]$$

$$K_H = 1 / [1 - 0.0047(62 - 75)] = 0.9424$$

$$CO_e = [1 - 0.01925 (1.43) - 0.000323 (48)] 306.0 = 293.4 \text{ ppm}$$

$$CO_d = [1 - 0.000323 (48)] 15.3 = 15.1 \text{ ppm}$$

$$DF = 13.4 / [1.43 + (105.8 + 293.4) \times 10^{-4}] = 9.116$$

$$HC_{conc} = 105.8 - 12.1(1 - 1/9.116) = 95.03 \text{ ppm}$$

$$HC_{mass} = (2595) (16.33) (95.03/1,000,000) = 4.027 \text{ grams per test phase.}$$

$$NOx_{conc} = 11.2 - 0.8 (1 - 1/9.116) = 10.49 \text{ ppm}$$

$$NOx_{mass} = (2595) (54.16) (10.49/1,000,000) (0.9424) = 1.389 \text{ grams per test phase.}$$

$$CO_{conc} = 293.4 - 15.1 (1 - 1/9.116) = 280.0 \text{ ppm}$$

$$CO_{mass} = (2595) (32.97) (280/1,000,000) = 23.96 \text{ grams per test phase.}$$

(2) For the stabilized portion of the cold start test assume that similar calculations resulted in the following:

$$\text{HC}_{\text{mass}} = 0.62 \text{ grams per test phase}$$

$$\text{NOx}_{\text{mass}} = 1.27 \text{ grams per test phase}$$

$$\text{CO}_{\text{mass}} = 5.98 \text{ grams per test phase}$$

(3) For the "transient" portion of the hot start test assume that similar calculations resulted in the following:

$$\text{HC}_{\text{mass}} = 0.51 \text{ grams per test phase}$$

$$\text{NOx}_{\text{mass}} = 1.38 \text{ grams per test phase}$$

$$\text{CO}_{\text{mass}} = 5.01 \text{ grams per test phase}$$

(4) Weighted mass emission results:

$$\text{HC}_{\text{wm}} = [(0.43) (4.027) + (0.57) (0.51) + 0.62] / 7.5 = 0.352 \text{ grams per vehicle mile.}$$

$$\text{NOx}_{\text{wm}} = [(0.43) (1.389) + (0.57) (1.38) + 1.27] / 7.5 = 0.354 \text{ grams per vehicle mile.}$$

$$\text{CO}_{\text{wm}} = [(0.43) (23.96) + (0.57) (5.01) + 5.98] / 7.5 = 2.55 \text{ grams per vehicle mile.}$$

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