

§ 86.1310-90 Exhaust gas sampling and analytical system; diesel engines.

(a) *General.* The exhaust gas sampling system described in this paragraph is designed to measure the true mass of both gaseous and particulate emissions in the exhaust of petroleum-fueled, natural gas-fueled, liquefied petroleum gas-fueled and methanol-fueled heavy-duty diesel engines. This system utilizes the CVS concept (described in § 86.1309) of measuring the combined mass emissions of HC, CH₃OH and HCHO from methanol-fueled engines and CO, CO₂ and particulate from all fuel types. A continuously integrated system is required for THC (petroleum-fueled, natural gas-fueled, and liquefied petroleum gas-fueled engines) and NO_x (all engines) measurement, and is allowed for all CO and CO₂ measurements plus the combined emissions of CH₃OH, HCHO, and HC from methanol-fueled

engines. Where applicable, separate sampling systems are required for methanol and for formaldehyde. The mass of gaseous emissions is determined from the sample concentration and total flow over the test period. The mass of particulate emissions is determined from a proportional mass sample collected on a filter and from the sample flow and total flow over the test period. As an option, the measurement of total fuel mass consumed over a cycle may be substituted for the exhaust measurement of CO₂. General requirements are as follows:

(1) This sampling system requires the use of a PDP-CVS and a heat exchanger, a CFV-CVS (or an EFC-CFV-CVS) with either a heat exchanger or electronic flow compensation. Figure N90-5 is a schematic drawing of the PDP system. Figure N90-6 is a schematic drawing of the CFV-CVS system.

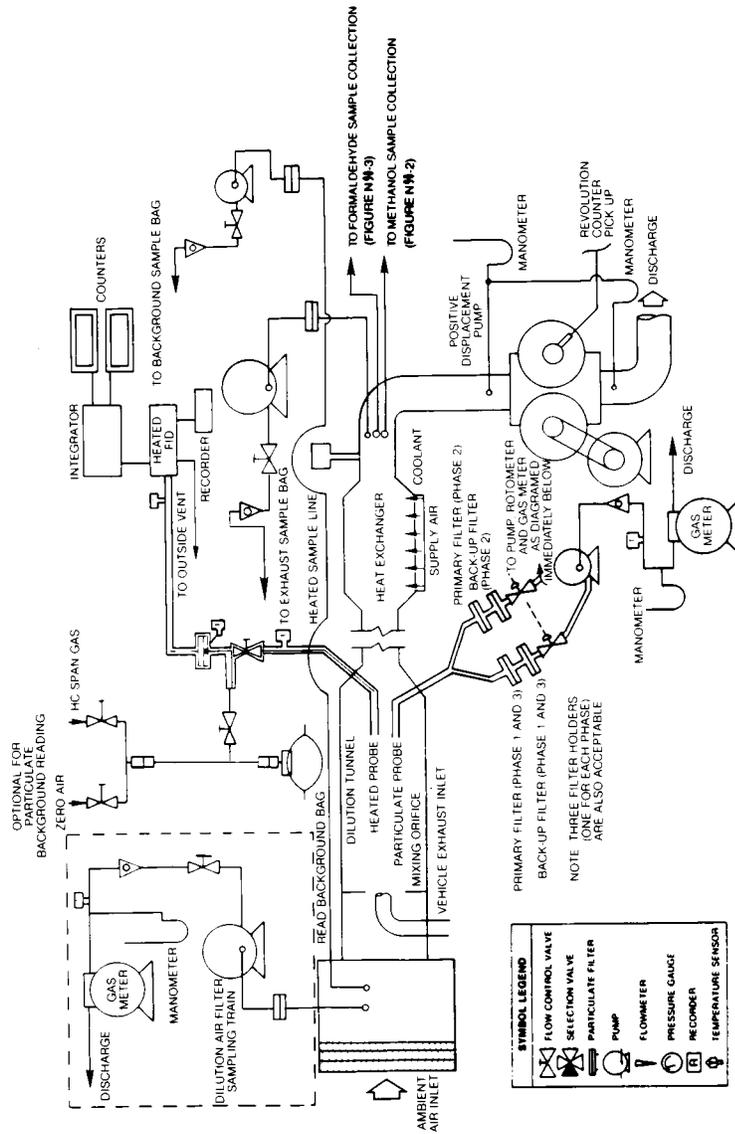


FIGURE N4-5
GASEOUS AND PARTICULATE EMISSIONS SAMPLING SYSTEM (PDP-CVS)

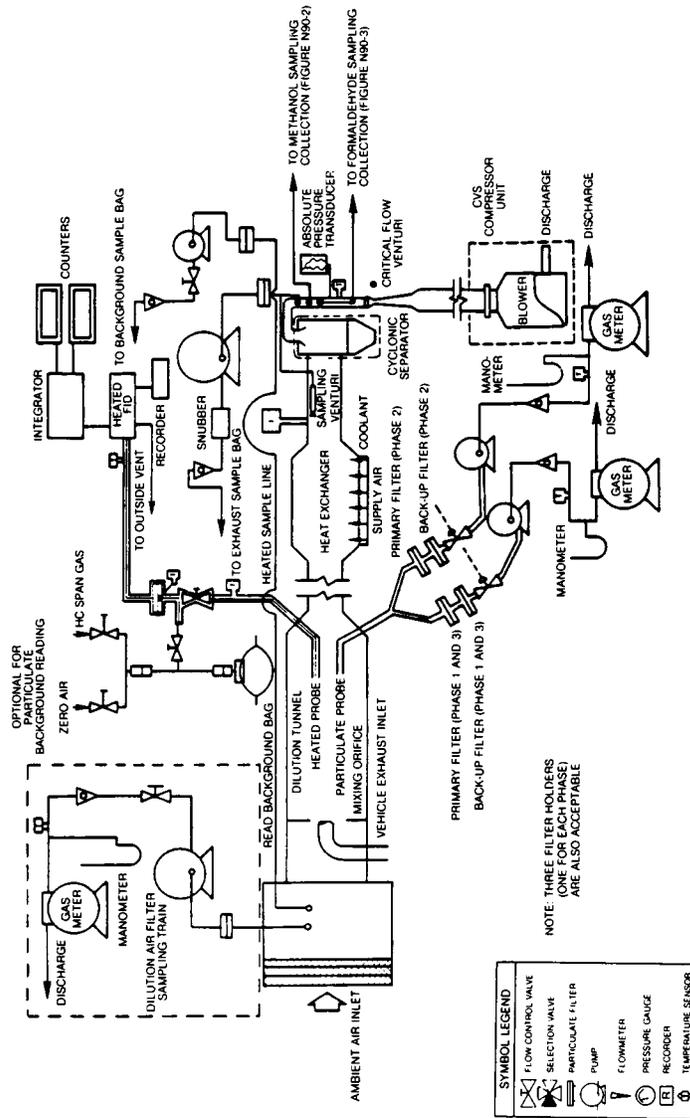


FIGURE N90-6
 GASEOUS AND PARTICULATE EMISSIONS SAMPLING SYSTEM (CFV-CVS)

(2) The HC analytical system for petroleum-fueled diesel engines requires a heated flame ionization detector (HFID) and heated sample system (375 ±20 °F (191 ±11 °C)). For natural gas-fueled and liquefied petroleum gas-fueled diesel engines either a heated flame ionization detector and heated sample system as required for petro-

leum fuel or a non-heated flame ionization detector may be used.

(3) Methanol-fueled engines require the use of a heated flame ionization detector (HFID) (235±15 °F (113±8 °C)) for hydrocarbon analysis. With a heated FID, the hydrocarbon analysis can be made on the bag sample and the methanol and formaldehyde analyses are

performed on the samples collected for these purposes (Figures N90-2 and N90-3).

NOTE: For 1990 through 1994 model year methanol-fueled engines, methanol and formaldehyde sampling may be omitted provided the hydrocarbon plus methanol analyses are performed using a FID calibrated on methanol.

(4) For methanol-fueled engines, cooling or reaction of the exhaust gases in the exhaust duct connected to the dilution tunnel (for the purposes of this paragraph, the exhaust duct excludes the length of pipe representative of the vehicle exhaust pipe) shall be minimized. This may be accomplished by:

(i) Using a duct of unrestricted length maintained at a temperature below 599 °F (315 °C). (Heating and possibly cooling capabilities as required); or

(ii) Using a smooth wall duct less than five feet long with no required heating (a maximum of two short flexible connectors are allowed under this option); or

(iii) Omitting the duct and performing the exhaust gas dilution function at the engine exhaust manifold or immediately after exhaust aftertreatment systems, or after a length of pipe representative of the vehicle exhaust pipe; or

(iv) Partial dilution of the exhaust gas prior to entering the dilution tunnel, which lowers the duct temperature below 599 °F (315 °C).

(5) Heated sample lines are required for the methanol and formaldehyde samples (care must be taken to prevent heating of the sample probes unless compensation for varying flow rate is made). The sample collection lines shall be heated to a temperature more than 5 °F (3 °C) above the maximum dew point of the mixture, but below 250 °F (121 °C).

(6) The CO and CO₂ analytical system requires:

(i) Bag sampling (§ 86.1309) and analytical (§ 86.1311) capabilities, as shown in Figure N90-5 (or Figure N90-6), or

(ii) Continuously integrated measurement of diluted CO and CO₂ meeting the minimum requirements and technical specifications contained in paragraph (b)(5) of this section. Unless compensation for varying flow is made, a

constant flow system must be used to ensure a representative sample.

(7) The NO_x analytical system requires a continuously integrated measurement of diluted NO_x meeting the minimum requirements and technical specifications contained in paragraph (b)(5) of this section. Unless compensation for varying flow is made, a constant flow system must be used to ensure a representative sample.

(8) The mass of particulate in the exhaust is determined via filtration. The particulate sampling system requires dilution of the exhaust in either one or two steps to a temperature never greater than 125 °F (51.7 °C) at the primary sample filter. A backup filter provides a confirmation of sufficient filtering efficiency.

(9) Since various configurations can produce equivalent results, exact conformance with these drawings 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. Other components, such as snubbers, which are not needed to maintain accuracy on some systems, may be excluded if their exclusion is based upon good engineering judgment.

(10) Other sampling and/or analytical systems may be used if shown to yield equivalent results and if approved in advance by the Administrator.

(b) *Component description.* The components necessary for exhaust sampling shall meet the following requirements:

(1) *Exhaust dilution system.* The PDP-CVS shall conform to all of the requirements listed for the exhaust gas PDP-CVS in § 86.1309(b). The CFV-CVS shall conform to all of the requirements listed for the exhaust gas CFV-CVS in § 86.1309(c). The EFC-CFV-CVS shall conform to all of the requirements listed for the exhaust gas EFC-CVS in § 86.1309(d). In addition, the CFV-CVS and EFC-CFV-CVS must conform to the following requirements:

(i) The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream at or below the temperatures required for the measurement of particulate and hydrocarbon emission noted below and at, or above, the temperatures where condensation

of water in the exhaust gases could occur. This may be achieved by either of the following two methods:

(A) *Single-dilution method.* The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream at a temperature of 125 °F (51.7 °C) or less, at the sampling zone in the primary dilution tunnel and as required to prevent condensation at any point in the dilution tunnel. Direct sampling of the particulate material may then take place (Figure N90-5).

(B) *Double-dilution method.* The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream in the primary dilution tunnel at a temperature of 375 °F (191 °C) (250 °F (121 °C) for methanol fueled engines) or less at the sampling zone and as required to prevent condensation at any point in the dilution tunnel. Gaseous emission samples may be taken directly from this sampling point. An exhaust sample must then be taken at this point to be diluted a second time for use in determining particulate emissions. The secondary dilution system must provide sufficient secondary dilution air to maintain the double-diluted exhaust stream at a temperature of 125 °F (51.7 °C) or less immediately before the primary particulate filter in the secondary dilution tunnel.

(ii) For the CFV-CVS or EFC-CFV-CVS, either a heat exchanger or electronic flow compensation (which also includes the particulate sample flows) is required (see Figure N90-6).

(iii) For the CFV-CVS or EFC-CFV-CVS when a heat exchanger is used, the gas mixture temperature, measured at a point immediately ahead of the crit-

ical flow venturi, shall be within ± 20 °F (± 11 °C) of the average operating temperature observed during the test with the simultaneous requirement that condensation does not occur. The temperature measuring system (sensors and readout) shall have an accuracy and precision of ± 3.4 °F (1.9 °C). For systems utilizing a flow compensator to maintain proportional sampling, the requirement for maintaining constant temperature is not necessary.

(iv) The primary dilution air and secondary dilution air (if applicable):

(A) Shall have a temperature of 77 ± 9 °F (25 ± 5 °C). For the first 10 seconds this specification is 77 ± 20 °F (25 ± 11 °C).

(B) May be filtered at the dilution air inlet.

(C) Primary dilution air may be sampled to determine background particulate levels, which can then be subtracted from the values measured in the diluted exhaust stream. The primary dilution air shall be sampled at the inlet to the primary dilution tunnel, if unfiltered, or downstream of any primary dilution air conditioning devices, if used.

(2) [Reserved]

(3) *Continuous HC measurement system.*

(i) The continuous HC sample system (as shown in Figure N90-7 or N90-8) uses an "overflow" zero and span system. In this type of system, excess zero or span gas spills out of the probe when zero and span checks of the analyzer are made. The "overflow" system may also be used to calibrate the HC analyzer per § 86.1321(b), although this is not required.

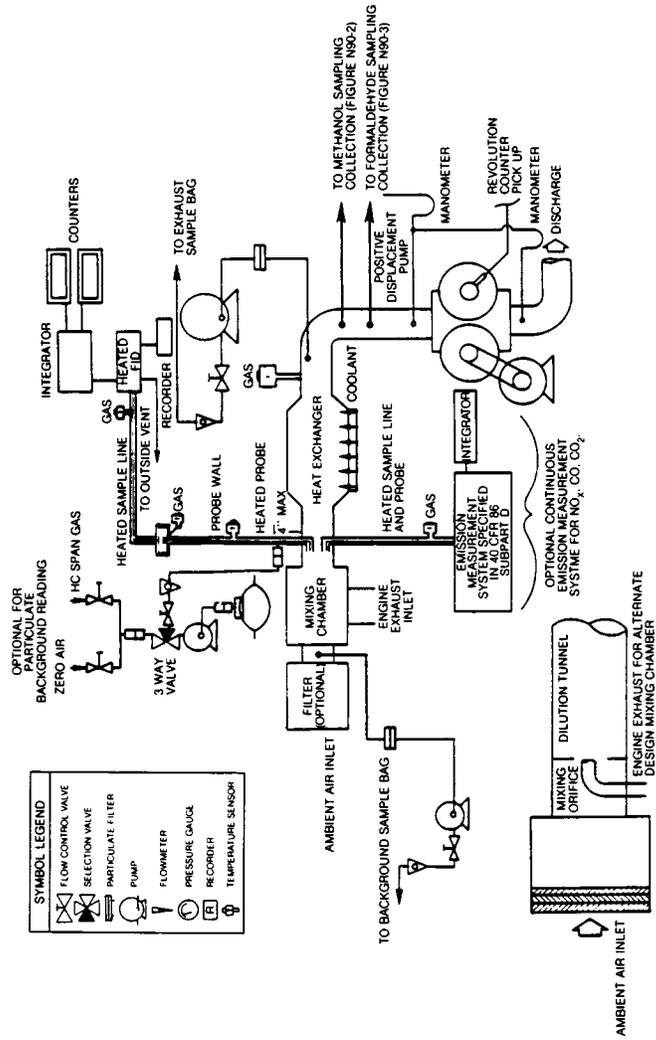


FIGURE N90-7 GASEOUS EMISSIONS SAMPLING SYSTEM (PDP-CVS)

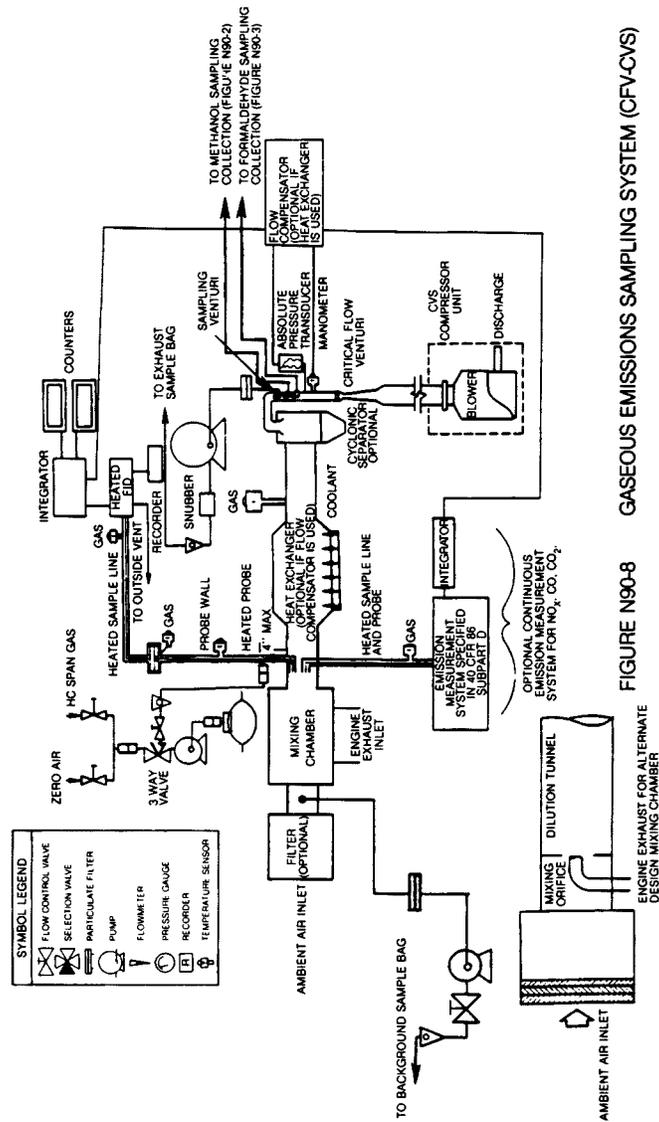


FIGURE N90-8 GASEOUS EMISSIONS SAMPLING SYSTEM (CFV-CVS)

- (ii) No other analyzers may draw a sample from the continuous HC sample probe, line or system, unless a common sample pump is used for all analyzers and the sample line system design reflects good engineering practice.
- (iii) The overflow gas flow rates into the sample line shall be at least 105 percent of the sample system flow rate.

- (iv) The overflow gases shall enter the heated sample line as close as practicable to the outside surface of the CVS duct or dilution tunnel.
- (v) The continuous HC sampling system shall consist of a probe (which must raise the sample to the specified temperature) and, where used, a sample transfer system (which must maintain

the specified temperature). The continuous hydrocarbon sampling system (exclusive of the probe) shall:

(A) Maintain a wall temperature of $464\text{K} \pm 11\text{K}$ ($191\text{ }^\circ\text{C} \pm 11\text{ }^\circ\text{C}$) as measured at every separately controlled heated component (i.e., filters, heated line sections), using permanent thermocouples located at each of the separate components.

(B) Have a wall temperature of $464\text{K} \pm 11\text{K}$ ($191\text{ }^\circ\text{C} \pm 11\text{ }^\circ\text{C}$) over its entire length. The temperature of the system shall be demonstrated by profiling the thermal characteristics of the system at initial installation and after any major maintenance performed on the system. The temperature profile of the HC sampling system shall be demonstrated by inserting thermocouple wires (typically Teflon[®] coated for ease of insertion) into the sampling system assembled in-situ where possible, using good engineering judgement. The wire should be inserted up to the HFID inlet. Stabilize the sampling system heaters at normal operating temperatures. Withdraw the wires in increments of 5 cm to 10 cm (2 inches to 4 inches) including all fittings. Record the stabilized temperature at each position. The system temperature will be monitored during testing at the locations and temperature described in § 86.1310-90(b)(v)(A). Comment: It is understood that profiling of the sample line can be done under flowing conditions also as required with the probe.

(C) Maintain a gas temperature of $464\text{K} \pm 11\text{K}$ ($191\text{ }^\circ\text{C} \pm 11\text{ }^\circ\text{C}$) immediately before the heated filter and HFID. These gas temperatures will be determined by a temperature sensor located immediately upstream of each component.

(vi) The continuous hydrocarbon sampling probe shall:

(A) Be defined as the first 25.4 cm (10 in) to 76.2 cm (30 in) of the continuous hydrocarbon sampling system.

(B) Have a 0.483 cm (0.19 in) minimum inside diameter.

(C) Be installed in the primary dilution tunnel at a point where the dilution air and exhaust are well mixed (i.e., approximately 10 tunnel diameters downstream of the point where the exhaust enters the dilution tunnel).

(D) Be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influence of any wakes or eddies.

(E) Increase the gas stream temperature to $464\text{K} \pm 11\text{K}$ ($191\text{ }^\circ\text{C} \pm 11\text{ }^\circ\text{C}$) by the exit of the probe. The ability of the probe to accomplish this shall be demonstrated at typical sample flow rates using the insertion thermocouple technique at initial installation and after any major maintenance. Compliance with the temperature specification shall be demonstrated by monitoring during each test the temperature of either the gas stream or the wall of the sample probe at its terminus.

(vii) The response time of the continuous measurement system shall be no greater than:

(A) 1.5 seconds from an instantaneous step change at the port entrance to the analyzer to within 90 percent of the step change.

(B) 20 seconds from an instantaneous step change at the entrance to the sample probe or overflow span gas port to within 90 percent of the step change. Analysis system response time shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets if necessary.

(C) For the purpose of verification of response times, the step change shall be at least 60 percent of full-scale chart deflection.

(4) *Primary-dilution tunnel.* (i) The primary dilution tunnel shall be:

(A) Small enough in diameter to cause turbulent flow (Reynolds Number greater than 4000) and of sufficient length to cause complete mixing of the exhaust and dilution air;

(B) At least 18 inches (46 cm) in diameter with a single-dilution system or at least 8 inches (20 cm) in diameter with a double-dilution system;

(C) Constructed of electrically conductive material which does not react with the exhaust components; and

(D) Electrically grounded.

(ii) The temperature of the diluted exhaust stream inside of the primary dilution tunnel shall be sufficient to prevent water condensation.

(iii) The engine exhaust shall be directed downstream at the point where it is introduced into the primary dilution tunnel.

(5) *Continuously integrated NO_x, CO, and CO₂ measurement systems.* (i) The sample probe shall:

(A) Be in the same plane as the continuous HC probe, but shall be sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influences of any wakes or eddies.

(B) Heated and insulated over the entire length, to prevent water condensation, to a minimum temperature of 131 °F (55 °C). Sample gas temperature immediately before the first filter in the system shall be at least 131 °F (55 °C).

(ii) The continuous NO_x, CO, or CO₂ sampling and analysis system shall conform to the specifications of 40 CFR part 86, subpart D, with the following exceptions and revisions:

(A) The system components required to be heated by subpart D need only be heated to prevent water condensation, the minimum component temperature shall be 131 °F (55 °C).

(B) The system response defined in § 86.329-79 shall be no greater than 20 seconds. Analysis system response time shall be coordinated with CVS flow fluctuations and sampling time/test cycle offsets, if necessary.

(C) Alternative NO_x measurement techniques outlined in § 86.346-79 are not permitted for NO_x measurement in this subpart.

(D) All analytical gases shall conform to the specifications of § 86.1314.

(E) Any range on a linear analyzer below 155 ppm shall have and use a calibration curve conforming to § 86.330-79.

(F) The measurement accuracy requirements specified in § 86.338-79 are superseded by those specified in § 86.1338.

(iii) The chart deflections or voltage output of analyzers with non-linear calibration curves shall be converted to concentration values by the calibration curve(s) specified in subpart D (§ 86.330-79) before flow correction (if used) and subsequent integration takes place.

(6) *Particulate sampling system.* The particulate collection system must be configured in either of two ways. The single-dilution method collects a proportional sample from the primary tunnel, and then passes this sample through the collection filter. The dou-

ble-dilution method collects a proportional sample from the primary tunnel, and then transfers this sample to a secondary dilution tunnel where the sample is further diluted; the double-diluted sample is then passed through the collection filter. Proportionality (i.e., mass flow ratio) between the primary tunnel flow rate and the sample flow rate must be maintained within ±5 percent. The requirements for these two systems are:

(i) *Single dilution method.* (A) The particulate sample probe shall be:

(1) Installed facing upstream at a point where the dilution air and exhaust air are well mixed (i.e., on the primary tunnel centerline, approximately 10 tunnel diameters downstream of the point where the exhaust enters the primary dilution tunnel).

(2) Sufficiently distant (radially) from other sampling probes so as to be free from the influence of any wakes or eddies produced by the other probes.

(3) 0.5 in. (1.3 cm) minimum inside diameter.

(4) The distance from the sampling tip to the filter holder shall be at least 5 probe diameters for filters located inside the primary dilution tunnel, and not more than 40 inches (102 cm) for filters located outside the primary dilution tunnel.

(5) Designed to minimize the deposition of particulate in the probe (i.e., bends should be as gradual as possible, protrusions (due to sensors, etc.) should be smooth and not sudden, etc.).

(B) The particulate sample pump(s) shall be located sufficiently distant from the dilution tunnel so that the inlet gas temperature is maintained at a constant temperature (±5 °F (±2.8 °C)) if flow compensation is not used.

(C) The gas meters or flow instrumentation shall be located sufficiently distant from the tunnel so that the inlet gas temperature remains constant (±5 °F (±2.8 °C)) if flow compensation is not used.

(D) Other sample flow handling and/or measurement systems may be used if shown to yield equivalent results and if approved in advance by the Administrator.

(ii) *Double-dilution method.* (A) The particulate sample transfer tube shall be configured and installed so that:

(1) The inlet faces upstream in the primary dilution tunnel at a point where the primary dilution air and exhaust are well mixed (*i.e.*, on the primary tunnel centerline, approximately 10 tunnel diameters downstream of the point where the exhaust enters the primary dilution tunnel).

(2) The particulate sample exits on the centerline of the secondary tunnel and points downstream.

(B) The particulate sample transfer tube shall be:

(1) Sufficiently distant (radially) from other sampling probes (in the primary dilution tunnel) so as to be free from the influence of any wakes or eddies produced by the other probes.

(2) 0.5 in (1.3 cm) minimum inside diameter.

(3) No longer than 36 in (91 cm) from inlet plane to exit plane.

(4) Designed to minimize the deposition of particulate during transfer (*i.e.*, bends should be as gradual as possible, protrusions (due to sensors, etc.) should be smooth and not sudden, etc.).

(5) Constructed of electrically conductive material which does not react with the exhaust components, and electrically grounded.

(C) The secondary dilution air shall be at a temperature of 77 ± 9 °F (25 ± 5 °C). For the first 10 seconds this specification is 77 ± 20 °F (25 ± 11 °C).

(D) The secondary-dilution tunnel shall be:

(1) 3.0 inches (7.6 cm) minimum inside diameter.

(2) Of sufficient length so as to provide a residence time of at least 0.25 seconds for the double-diluted sample.

(3) Constructed of electrically conductive material which does not react with the exhaust components, and electrically grounded.

(E) Additional dilution air must be provided so as to maintain a sample temperature of 125 °F (51.7 °C) or less immediately before the primary sample filter.

(F) The primary filter holder shall be located within 12.0 in (30.5 cm) of the exit of the secondary dilution tunnel.

(G) Other sample flow handling and/or measurement systems may be used if shown to yield equivalent results and if approved in advance by the Administrator.

(7) *Particulate sampling filters.* (i) Fluorocarbon-coated glass fiber filters or fluorocarbon-based (membrane) filters are required.

(ii) Particulate filters must have a minimum diameter of 70 mm (60 mm stain diameter). Larger diameter filters are acceptable.

(iii) The dilute exhaust will be simultaneously sampled by a pair of filters (one primary and one back-up filter) during the cold-start test and by a second pair of filters during the hot-start test. The back-up filter holder shall be located no more than 4 inches (10 cm) downstream of the primary filter holder. The primary and back-up filters shall not be in contact with each other.

(iv) It is recommended that the filter loading should be maximized consistent with other temperature requirements and the requirement to avoid moisture condensation. A filter pair loading of 1 mg is typically proportional to a 0.1 g/bhp-hr emission level. All particulate filters, reference filters, and background filters shall be handled in pairs during all weighing operations for emissions testing.

(8) *Methanol sampling system.* The methanol sampling system, shown in Figure N90-2, consists of impingers (or sample collection capsules) containing known volumes of deionized water and sampling pump to draw the proportional sample through the impingers.

(9) *Formaldehyde sampling system.* The formaldehyde sampling system, Figure N90-3, consists of sample collection impingers and sampling pump to draw the proportional sample through the impingers.

[54 FR 14578, Apr. 11, 1989, as amended at 59 FR 48525, Sept. 21, 1994; 60 FR 34370, June 30, 1995; 62 FR 47124, Sept. 5, 1997]

§ 86.1311-90 Exhaust gas analytical system; CVS bag sample.

(a) *Schematic drawings.* Figure N90-9 is a schematic drawing of the exhaust gas analytical system used for analyzing CVS bag samples from either Otto-cycle or diesel engines. Since various configurations can produce accurate results, exact conformance with the drawing is not required. Additional components such as instruments, valves, solenoids, pumps and switches