

rate of the dilute engine exhaust as described in §91.421.

(3) *Exhaust sample port.* A dilute exhaust sample port must be located in or downstream of the mixing tunnel at a point where complete mixing of the engine exhaust and background air is assured.

(4) *Background sample port.* A dilute background sample port must be located in the stream of background air before it is mixed with the engine exhaust. The background probe must draw a representative sample of the background air during each sampling mode.

(5) *Exhaust sampling system.* The dilute exhaust sampling system controls the flow of samples from the mixing tunnel to the analyzer system. This could be either a continuous sampling system or grab (bag) sampling system. If a critical flow venturi (CFV) is used on the dilute exhaust sample probe, this system must assure that the sample CFV is in choke flow during testing. If no CFV is used, this system must assure a constant volumetric flow rate through the dilute exhaust sample probe or must incorporate electronic flow compensation.

(6) *Background sampling system.* The background sampling system controls the flow of samples from the background air supply to the analyzer system. This could be either a continuous sampling system or grab (bag) sampling system. This system must assure a constant volumetric flow rate through the background sample probe.

**§91.421 Dilute gaseous exhaust sampling and analytical system description.**

(a) General. The exhaust gas sampling system described in this section is designed to measure the true mass emissions of engine exhaust. This system utilizes the Constant volume Sampling (CVS) concept (described in §91.420) of measuring mass emissions of HC, NO<sub>x</sub>, CO, and CO<sub>2</sub>. Grab sampling for individual modes is an acceptable method of dilute testing for all constituents, HC, NO<sub>x</sub>, CO, and CO<sub>2</sub>. Continuous dilute sampling is not required for any of the exhaust constituents, but is allowable for all. Heated sampling is not required for any of the con-

stituents, but is allowable for HC and NO<sub>x</sub>. The mass of gaseous emissions is determined from the sample concentration 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 CO<sub>2</sub>. General requirements are as follows:

(1) This sampling system requires the use of a Positive Displacement Pump—Constant Volume Sampler (PDP-CVS) system with a heat exchanger, or a Critical Flow Venturi—Constant Volume Sampler (CFV-CVS) system with CVS sample probes and/or a heat exchanger or electronic flow compensation. Figure 2 in appendix B of this subpart is a schematic drawing of the PDP-CVS system. Figure 3 in appendix B of this subpart is a schematic drawing of the CFV-CVS system.

(2) The HC analytical system requires:

(i) Grab sampling (see §91.420, and Figure 2 or Figure 3 in appendix B of this subpart) and analytical capabilities (see §91.423, and Figure 4 in appendix B of this subpart), or

(ii) Continuously integrated measurement of diluted HC meeting the minimum requirements and technical specifications contained in paragraph (b)(2) of this section.

(iii) The dilute HC analytical system for marine spark-ignition engines does not require a heated flame ionization detector (HFID).

(iv) If used, the HFID sample must be taken directly from the diluted exhaust stream through a heated probe and integrated continuously over the test cycle.

(v) The heated probe must be located in the sampling system far enough downstream of the mixing area to ensure a uniform sample distribution across the CVS duct at the sampling zone.

(3) The CO and CO<sub>2</sub> analytical system requires:

(i) Grab sampling (see §91.420, and Figure 2 or Figure 3 in appendix B of this subpart) and analytical capabilities (see §91.423, and Figure 4 in appendix B of this subpart), or

(ii) Continuously integrated measurement of diluted CO and CO<sub>2</sub> meeting

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the minimum requirements and technical specifications contained in paragraph (b)(4) of this section.

(4) The NO<sub>x</sub> analytical system requires:

(i) Grab sampling (see §91.420, and Figure 2 or Figure 3 in appendix B of this subpart) and analytical capabilities (see §91.423, and Figure 4 in appendix B of this subpart), or

(ii) A continuously integrated measurement of diluted NO<sub>x</sub> meeting the minimum requirements and technical specifications contained in paragraph (b)(4) of this section.

(5) 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.

(6) 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 must meet the following requirements:

(1) *Exhaust dilution system.* The PDP-CVS must conform to all of the requirements listed for the exhaust gas PDP-CVS in §91.420 of this chapter. The CFV-CVS must conform to all of the requirements listed for the exhaust gas CFV-CVS in §91.420. In addition, the CVS must conform to the following requirements:

(i) The flow capacity of the CVS must be sufficient to maintain the diluted exhaust stream in the dilution system at a temperature of 190 °C or less at the sampling zone for hydrocarbon measurement and as required to prevent condensation at any point in the dilution system. Gaseous emission samples may be taken directly from this sampling point.

(ii) For the CFV-CVS, either a heat exchanger or electronic flow compensation is required (see Figure 3 in appendix B of this subpart).

(iii) For the CFV-CVS when a heat exchanger is used, the gas mixture temperature, measured at a point immediately ahead of the critical flow venturi, must be within  $\pm 11$  °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) must have an accuracy and precision of  $\pm 2$  °C. For systems utilizing a flow compensator to maintain proportional flow, the requirement for maintaining constant temperature is not necessary.

(2) *Continuous HC measurement system.*

(i) The continuous HC sample system (as shown in Figure 2 or 3 in appendix B of this subpart) 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.

(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 must be at least 105 percent of the sample system flow rate.

(iv) The overflow gases must enter the sample line as close as practical to the outside surface of the CVS duct or dilution system.

(v) The continuous HC sampling system consists of a probe (which for a HFID analyzer must raise the sample to the specified temperature) and, where used, a sample transfer system (which for a HFID must maintain the specified temperature). The HFID continuous hydrocarbon sampling system (exclusive of the probe) must:

(A) Maintain a wall temperature of  $190 \pm 11$  °C as measured at every separately controlled heated component (that is, filters, heated line sections), using permanent thermocouples located at each of the separate components.

(B) Have a wall temperature of  $190 \pm 11$  °C over its entire length. The temperature of the system is demonstrated by profiling the thermal characteristics of the system where possible at initial installation and after any major maintenance performed on the system.

The profiling is to be accomplished using the insertion thermocouple probing technique. The system temperature must be monitored continuously during testing at the locations and temperature described in §91.421(b)(2).

(C) Maintain a gas temperature of 190 ±11 °C immediately before the heated filter and HFID. Determine these gas temperatures by a temperature sensor located immediately upstream of each component.

(vi) The continuous hydrocarbon sampling probe:

(A) Is defined as the first 25.4 to 76.2 cm of the continuous hydrocarbon sampling system.

(B) Has a 0.483 cm minimum inside diameter.

(C) Is installed in the dilution system at a point where the dilution air and exhaust are well mixed and provide a homogenous mixture.

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

(E) For a continuous HFID sample probe, the probe must increase the gas stream temperature to 190 ±11 °C at the exit of the probe. Demonstrate the ability of the probe to accomplish this using the insertion thermocouple technique at initial installation and after any major maintenance. Demonstrate compliance with the temperature specification by continuously recording 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 must be taken into account when logging test data.

(3) *Sample mixing.* (i) configure the dilution system to ensure a well mixed, homogeneous sample prior to the sampling probe(s).

(ii) Make the temperature of the diluted exhaust stream inside the dilution system sufficient to prevent water condensation.

(iii) Direct the engine exhaust downstream at the point where it is introduced into the dilution system.

(4) *Continuously integrated NO<sub>x</sub>, CO, and CO<sub>2</sub> measurement systems.* (i) Sample probe requirements:

(A) The sample probe for continuously integrated NO<sub>x</sub>, CO, and CO<sub>2</sub> must be in the same plane as the continuous HC probe, but sufficiently distant (radially) from other probes and the tunnel wall so as to be free from the influences of any wakes or eddies.

(B) The sample probe for continuously integrated NO<sub>x</sub>, CO, and CO<sub>2</sub> must be heated and insulated over the entire length, to prevent water condensation, to a minimum temperature of 55 °C. Sample gas temperature immediately before the first filter in the system must be at least 55 °C.

(ii) Conform to the continuous NO<sub>x</sub>, CO, or CO<sub>2</sub> sampling and analysis system to the specifications of 40 CFR 1065.145, with the following exceptions and revisions:

(A) Heat the system components requiring heating only to prevent water condensation, the minimum component temperature is 55 °C.

(B) Coordinate analysis system response time with CVS flow fluctuations and sampling time/test cycle offsets to meet the time-alignment and dispersion specifications in 40 CFR part 1065, subpart C.

(C) Use only analytical gases conforming to the specifications of 40 CFR 1065.750 for calibration, zero, and span checks.

(D) Use a calibration curve conforming to 40 CFR part 1065, subparts C and D, for CO, CO<sub>2</sub>, and NO<sub>x</sub> for any range on a linear analyzer below 155 ppm.

(iii) Convert the chart deflections or voltage output of analyzers with non-linear calibration curves to concentration values by the calibration curve(s) specified in 40 CFR part 1065, subpart D, before flow correction (if used) and subsequent integration takes place.

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**§91.423 Exhaust gas analytical system; CVS grab sample.**

(a) *Schematic drawings.* Figure 4 in appendix B of this subpart is a schematic drawing of the exhaust gas analytical system used for analyzing CVS grab “bag” samples from spark-ignition engines. Since various configurations can