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credit calculation purposes that provide high levels of confidence that eligible production or sales are accurately counted.

(c) (1) End-of-year reports must be submitted within 90 days of the end of the model year to: Manager, Engine Compliance Programs Group (6403-J), U.S. Environmental Protection Agency, Washington, DC 20460.

(2) Unless otherwise approved by the Administrator, final reports must be submitted within 270 days of the end of the model year to: Manager, Engine Compliance Programs Group (6403-J), U.S. Environmental Protection Agency, Washington, DC 20460.

(d) Failure by a manufacturer to submit any end-of-year or final reports in the specified time for any engines subject to regulation under this part is a violation of § 90.1003(a)(2) and section 213(d) of the Clean Air Act for each engine.

(e) A manufacturer generating credits for banking only who fails to submit end-of-year reports in the applicable specified time period (90 days after the end of the model year) may not use the credits until such reports are received and reviewed by EPA. Use of projected credits pending EPA review is not permitted in these circumstances.

(f) Errors discovered by EPA or the manufacturer in the end-of-year report, including errors in credit calculation, may be corrected in the final report.

(g) If EPA or the manufacturer determines that a reporting error occurred on an end-of-year or final report previously submitted to EPA under this section, the manufacturer's credits and credit calculations must be recalculated. Erroneous positive credits will be void except as provided in paragraph (h) of this section. Erroneous negative credit balances may be adjusted by EPA.

(h) If EPA review determines a reporting error in the manufacturer's favor (that is, resulting in an increased credit balance) or if the manufacturer discovers such an error within 270 days of the end of the model year, EPA shall restore the credits for use by the manufacturer.

### § 90.211 Request for hearing.

An engine manufacturer may request a hearing on the Administrator's voiding of the certificate under §§ 90.203(h), 90.206(e), 90.207(f), 90.208(c), or 90.209(f), pursuant to § 90.124. The procedures of § 90.125 shall apply to any such hearing.

## Subpart D—Emission Test Equipment Provisions

### § 90.301 Applicability.

(a) This subpart describes the equipment required in order to perform exhaust emission tests on new nonroad spark-ignition engines and vehicles subject to the provisions of subpart A of this part. Certain text in this subpart is identified as pertaining to Phase 1 or Phase 2 engines. Such text pertains only to engines of the specified Phase. If no indication of Phase is given, the text pertains to all engines, regardless of Phase.

(b) Exhaust gases, either raw or dilute, are sampled while the test engine is operated using a steady state test cycle on an engine dynamometer. The exhaust gases receive specific component analysis determining concentration of pollutant. Emission concentrations are converted to mass emission rates in grams per hour based on either fuel flow, fuel flow and engine intake air flow, or exhaust volume flow. Weighted emission rates are reported as grams per brake-kilowatt hour (g/kW-hr). See subpart E of this part for a complete description of the test procedure.

(c) Additional information about system design, calibration methodologies, and so forth, for raw gas sampling can be found in part 86, subpart D of this chapter. Examples for system design, calibration methodologies, and so forth, for dilute exhaust gas sampling can be found in part 86, subpart N of this chapter.

(d) For Phase 2 Class I, and Phase 2 Class II natural gas fueled engines, the following sections from 40 CFR Part 86 are applicable to this subpart. The requirements of these sections which pertain specifically to the measurement and calculation of non-methane hydrocarbon (NMHC) exhaust emissions from otto cycle heavy-duty engines must be

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followed when determining the NMHC exhaust emissions from Phase 2 Class I, and Phase 2 Class II natural gas fueled engines. Those sections are: 40 CFR 86.1306-90 Equipment required and specifications; overview, 40 CFR 86.1309-90 Exhaust gas sampling system; otto-cycle engines, 40 CFR 86.1311-94 Exhaust gas analytical system; CVS bag sampling, 40 CFR 86.1313-94(e) Fuel Specification—Natural gas-fuel, 40 CFR 86.1314-94 Analytical gases, 40 CFR 86.1316-94 Calibrations; frequency and overview, 40 CFR 86.1321-94 Hydrocarbon analyzer calibration, 40 CFR 86.1325-94 Methane analyzer calibration, 40 CFR 86.1327-94 Engine dynamometer test procedures, overview, 40 CFR 86.1340-94 Exhaust sample analysis, 40 CFR 86.1342-94 Calculations; exhaust emissions, 40 CFR 86.1344-94(d) Required information—Pre-test data, 40 CFR 86.1344-94(e) Required information—Test data.

[60 FR 34598, July 3, 1995, as amended at 64 FR 15243, Mar. 30, 1999]

### § 90.302 Definitions.

The definitions in § 90.3 apply to this subpart. The following definitions also apply to this subpart.

*Intermediate speed* means the engine speed which is 85 percent of the rated speed.

*Natural gas* means a fuel whose primary constituent is methane.

*Rated speed* means the speed at which the manufacturer specifies the maximum rated power of an engine.

[64 FR 15243, Mar. 30, 1999]

### § 90.303 Symbols, acronyms, abbreviations.

(a) The acronyms and abbreviations in § 90.5 apply to this subpart.

(b) The symbols in Table 1 in Appendix A of this subpart apply to this subpart.

### § 90.304 Test equipment overview.

(a) All engines subject to this subpart are tested for exhaust emissions. Engines are operated on dynamometers meeting the specification given in § 90.305.

(b) The exhaust is tested for gaseous emissions using a raw gas sampling system as described in § 90.414 or a con-

stant volume sampling (CVS) system as described in § 90.421. Both systems require analyzers (see paragraph (c) of this section) specific to the pollutant being measured.

(c) Analyzers used are a non-dispersive infrared (NDIR) absorption type for carbon monoxide and carbon dioxide analysis; paramagnetic (PMD), zirconia (ZRDO), or electrochemical type (ECS) for oxygen analysis; a flame ionization (FID) or heated flame ionization (HFID) type for hydrocarbon analysis; and a chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD) for oxides of nitrogen analysis.

### § 90.305 Dynamometer specifications and calibration accuracy.

(a) *Dynamometer specifications.* The dynamometer test stand and other instruments for measurement of speed and power output must meet the engine speed and torque accuracy requirements shown in Table 2 in Appendix A of this subpart. The dynamometer must be capable of performing the test cycle described in § 90.410.

(b) *Dynamometer calibration accuracy.* (1) The dynamometer test stand and other instruments for measurement of power output must meet the calibration frequency shown in Table 2 in Appendix A of this subpart.

(2) A minimum of three calibration weights for each range used is required. The weights must be equally spaced and traceable to within 0.5 percent of National Institute for Standards and Testing (NIST) weights. Laboratories located in foreign countries may certify calibration weights to local government bureau standards.

### § 90.306 Dynamometer torque cell calibration.

(a)(1) Any lever arm used to convert a weight or a force through a distance into a torque must be used in a horizontal position for horizontal shaft dynamometers ( $\pm$  five degrees). For vertical shaft dynamometers, a pulley system may be used to convert the dynamometer's horizontal loading into the vertical plane.

(2) Calculate the indicated torque (IT) for each calibration weight to be used by:

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IT=Moment Arm (meters) × Calibration Weight (Newtons)

(3) Attach each calibration weight specified in § 90.305(b)(2) to the moment arm at the calibration distance determined in paragraph (a)(2) of this section. Record the power measurement equipment response (N-m) to each weight.

(4) Compare the torque value measured to the calculated torque.

(5) The measured torque must be within two percent of the calculated torque.

(6) If the measured torque is not within two percent of the calculated torque, adjust or repair the system. Repeat steps in paragraphs (a)(1) through (a)(6) of this section with the adjusted or repaired system.

(b) Option. A master load-cell or transfer standard may be used to verify the torque measurement system.

(1) The master load-cell and read out system must be calibrated using weights specified in § 90.305(b)(2).

(2) Attach the master load-cell and loading system.

(3) Load the dynamometer to a minimum of three equally spaced torque values as indicated by the master load-cell for each in-use range used.

(4) The in-use torque measurement must be within two percent of the torque measured by the master system for each load used.

(5) If the in-use torque is not within two percent of the master torque, adjust or repair the system. Repeat steps in paragraphs (b)(2) through (b)(4) of this section with the adjusted or repaired system.

(c) Calibrated resistors may not be used for engine flywheel torque transducer calibration, but may be used to span the transducer prior to engine testing.

(d) Other engine dynamometer system calibrations such as speed are performed as specified by the dynamometer manufacturer or as dictated by good engineering practice.

### § 90.307 Engine cooling system.

An engine cooling system is required with sufficient capacity to maintain the engine at normal operating temperatures as prescribed by the engine manufacturer. Auxiliary fan(s) may be

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used to maintain sufficient engine cooling during engine dynamometer operation.

#### **§ 90.308 Lubricating oil and test fuels.**

(a) *Lubricating oil.* Use the engine lubricating oil which meets the engine manufacturer's specifications for a particular engine and intended usage.

(1) Manufacturers must use engine lubricants representative of commercially available engine lubricants.

(2) For 2-stroke engines, the fuel/oil mixture ratio must be that which is recommended by the manufacturer.

(b) *Test Fuels—Certification.* (1) The manufacturer must use gasoline having the specifications, or substantially equivalent specifications approved by the Administrator, as specified in Table 3 in Appendix A of this subpart for exhaust emission testing of gasoline fueled engines. As an option, manufacturers may use the fuel specified in § 86.1313-94(a) of this chapter for gasoline fueled engines.

(2) Alternative fuels, such as natural gas, propane, and methanol, used for exhaust emission testing and service accumulation of alternative fuel spark-ignition engines must be representative of commercially available alternative fuels.

(i) The manufacturer shall recommend the alternative fuel to be used for certification testing and engine service accumulation in accordance with paragraph (b)(3) of this section.

(ii) The Administrator shall determine the alternative fuel to be used for testing and engine service accumulation, taking into consideration the alternative fuel recommended by the manufacturer.

(3) Other fuels may be used for testing provided:

(i) They are commercially viable;

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

(iii) Fuel specifications are approved in writing by the Administrator prior to the start of testing.

(c) *Test fuels—service accumulation and aging.* Unleaded gasoline representative of commercial gasoline generally available through retail outlets must be used in service accumulation and aging

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for gasoline-fueled spark-ignition engines. As an alternative, the certification test fuels specified under paragraph (b) of this section may be used for engine service accumulation and aging. Leaded fuel may not be used during service accumulation or aging.

[60 FR 34598, July 3, 1995, as amended at 64 FR 15243, Mar. 30, 1999]

### § 90.309 Engine intake air temperature measurement.

(a) The measurement location must be within 10 cm of the engine intake system (i.e., the air cleaner, for most engines.)

(b) The temperature measurements must be accurate to within  $\pm 2^{\circ}\text{C}$ .

### § 90.310 Engine intake air humidity measurement.

This section refers to engines which are supplied with intake air other than the ambient air in the test cell (i.e., air which has been pumped directly to the engine air intake system). For engines which use ambient test cell air for the engine intake air, the ambient test cell humidity measurement may be used.

(a) *Humidity conditioned air supply.* Air that has had its absolute humidity altered is considered humidity-conditioned air. For this type of intake air supply, the humidity measurements must be made within the intake air supply system and after the humidity conditioning has taken place.

(b) *Unconditioned air supply.* Humidity measurements in unconditioned intake air supply systems must be made in the intake air stream entering the supply system. Alternatively, the humidity measurements can be measured within the intake air supply stream.

### § 90.311 Test conditions.

(a) *General requirements.* (1) Ambient temperature levels encountered by the test engine throughout the test sequence may not be less than  $20^{\circ}\text{C}$  or more than  $30^{\circ}\text{C}$ . All engines must be installed on the test bed at their design installation angle to prevent abnormal fuel distribution.

(2) Calculate all volumes and volumetric flow rates at standard conditions for temperature and pressure, and use these conditions consistently throughout all calculations. Standard

conditions for temperature and pressure are  $25^{\circ}\text{C}$  and 101.3 kPa.

(b) *Engine test conditions.* Measure the absolute temperature (designated as T and expressed in Kelvin) of the engine air at the inlet to the engine and the dry atmospheric pressure (designated as  $p_s$  and expressed in kPa), and determine the parameter f according to the following provisions for naturally aspirated engines:

$$f = \frac{99}{p_s} \times \left( \frac{T}{298} \right)^{0.7}$$

For a certification test to be recognized as valid, the parameter f shall be between the limits as shown below:  $0.96 < f < 1.04$

### § 90.312 Analytical gases.

(a) The shelf life of a calibration gas may not be exceeded. The expiration date stated by the gas supplier must be recorded.

(b) *Pure gases.* The required purity of the gases is defined by the contamination limits specified in this subsection. The following gases must be available for operation:

(1) Purified nitrogen, also referred to as "zero-grade nitrogen" (Contamination  $\leq 1$  ppm C,  $\leq 1$  ppm CO,  $\leq 400$  ppm  $\text{CO}_2$ ,  $\leq 0.1$  ppm NO);

(2) Purified oxygen (Purity 99.5 percent vol O<sub>2</sub>);

(3) Hydrogen-helium mixture ( $40 \pm 2$  percent hydrogen, balance helium) (Contamination  $\leq 1$  ppm C,  $\leq 400$  ppm CO);

(4) Purified synthetic air, also referred to as "zero air" or "zero gas" (Contamination  $\leq 1$  ppm C,  $\leq 1$  ppm CO,  $\leq 400$  ppm  $\text{CO}_2$ ,  $\leq 0.1$  ppm NO) (Oxygen content between 18-21 percent vol.).

(c) *Calibration and span gases.* (1) Calibration gas values are to be derived from NIST "Standard Reference Materials" (SRM's) and are to be single blends as specified in this subsection.

(2) Mixtures of gases having the following chemical compositions must be available:

C<sub>3</sub>H<sub>8</sub> and purified synthetic air and/or C<sub>3</sub>H<sub>8</sub> and purified nitrogen;

CO and purified nitrogen;

NO<sub>x</sub> and purified nitrogen (the amount of NO<sub>2</sub> contained in this calibration gas must not exceed five percent of the NO content);

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CO<sub>2</sub> and purified nitrogen.

NOTE: For the HFID or FID the manufacturer may choose to use as a diluent span gas and the calibration gas either purified synthetic air or purified nitrogen. Any mixture of C<sub>3</sub> H<sub>8</sub> and purified synthetic air which contains a concentration of propane higher than what a gas supplier considers to be safe may be substituted with a mixture of C<sub>3</sub> H<sub>8</sub> and purified nitrogen. However, the manufacturer must be consistent in the choice of diluent (zero air or purified nitrogen) between the calibration and span gases. If a manufacturer chooses to use C<sub>3</sub> H<sub>8</sub> and purified nitrogen for the calibration gases, then purified nitrogen must be the diluent for the span gases.

(3) The true concentration of a span gas must be within  $\pm$  two percent of the NIST gas standard. The true concentration of a calibration gas must be within  $\pm$  one percent of the NIST gas standard. The use of precision blending devices (gas dividers) to obtain the required calibration gas concentrations is acceptable. Give all concentrations of calibration gas on a volume basis (volume percent or volume ppm).

(4) The gas concentrations used for calibration and span may also be obtained by means of a gas divider, diluting either with purified N<sub>2</sub> or with purified synthetic air. The accuracy of the mixing device must be such that the concentration of the diluted gases may be determined to within  $\pm$  two percent.

(d) Oxygen interference check gases must contain propane with 350 ppmC  $\pm$  75 ppmC hydrocarbon. Determine the concentration value to calibration gas tolerances by chromatographic analysis of total hydrocarbons plus impurities or by dynamic blending. For gasoline fueled engines, oxygen concentration must be between 0 and 1 percent O<sub>2</sub>. Nitrogen must be the predominant diluent with the balance oxygen.

(e) Fuel for the hydrocarbon flame ionization detector (HC-FID) must be a blend of 40  $\pm$  two percent hydrogen with the balance being helium. The mixture must contain less than one ppm equivalent carbon response; 98 to 100 percent hydrogen fuel may be used with advance approval of the Administrator.

(f) *Hydrocarbon analyzer burner air.* The concentration of oxygen must be within one mole percent of the oxygen

concentration of the burner air used in the latest oxygen interference check (percent O<sub>2</sub> I), see §90.316(d). If the difference in oxygen concentration is greater than one mole percent, then the oxygen interference must be checked and, if necessary, the analyzer adjusted to meet the percent O<sub>2</sub> I requirements. The burner air must contain less than two ppmC hydrocarbon.

### § 90.313 Analyzers required.

(a) *Analyzers.* Analyze measured gases with the following instruments:

(1) *Carbon monoxide (CO) analysis.* (i) The carbon monoxide analyzer shall be of the non-dispersive infrared (NDIR) absorption type.

(ii) The use of linearizing circuits is permitted.

(2) *Carbon dioxide (CO<sub>2</sub>) analysis.* (i) The carbon dioxide analyzer shall be of the non-dispersive infrared (NDIR) absorption type.

(ii) The use of linearizing circuits is permitted.

(3) *Oxygen (O<sub>2</sub>) analysis.* Oxygen (O<sub>2</sub>) analyzers may be of the paramagnetic (PMD), zirconia (ZRDO) or electrochemical type (ECS).

(4) *Hydrocarbon (HC) analysis.* (i) For Raw Gas Sampling, the hydrocarbon analyzer shall be of the heated flame ionization (HFID) type. For constant volume sampling, the hydrocarbon analyzer may be of the flame ionization (FID) type or of the heated flame ionization (HFID) type.

(ii) For the HFID system, if the temperature of the exhaust gas at the sample probe is below 190 °C, the temperature of the valves, pipe work, and so forth, must be controlled so as to maintain a wall temperature of 190 °C  $\pm$  11 °C. If the temperature of the exhaust gas at the sample probe is above 190 °C, the temperature of the valves, pipe work, and so forth, must be controlled so as to maintain a wall temperature greater than 180 °C.

(iii) For the HFID analyzer, the detector, oven, and sample-handling components within the oven must be suitable for continuous operation at temperatures to 200 °C. It must be capable of maintaining temperature within  $\pm$  5.5 °C of the set point.

(iv) Fuel and burner air must conform to the specifications in §90.312.

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(v) The percent of oxygen interference must be less than three percent, as specified in § 90.316(d).

(5) *Oxides of nitrogen (NO<sub>x</sub>) analysis.*

(i) This analysis device consists of the following items:

(A) A NO<sub>2</sub> to NO converter. The NO<sub>2</sub> to NO converter efficiency must be at least 90 percent.

(B) An ice bath located after the NO<sub>x</sub> converter (optional).

(C) A chemiluminescent detector (CLD) or heated chemiluminescent detector (HCLD).

(ii) The quench interference must be less than 3.0 percent as measured in § 90.325.

(b) *Other analyzers and equipment.* Other types of analyzers and equipment may be used if shown to yield equivalent results and if approved in advance by the Administrator.

(c) The following requirements must be incorporated as indicated in systems used for testing under this subpart.

(1) Carbon monoxide and carbon dioxide measurements must be made on a dry basis (for raw exhaust measurement only). Specific requirements for the means of drying the sample can be found in § 90.313(e).

(2) Calibration or span gases for the NO<sub>x</sub> measurement system must pass through the NO<sub>2</sub> to NO converter.

(d) The electromagnetic compatibility (EMC) of the equipment must be on a level as to minimize additional errors.

(e) *Gas drying.* Chemical dryers are not an acceptable method of removing water from the sample. Water removal by condensation is acceptable. If water is removed by condensation, the sample gas temperature or sample dew point must be monitored either within the water trap or downstream and its temperature must not exceed 7 °C. A water trap performing this function is an acceptable method. Means other than condensation may be used only with prior approval from the Administrator.

### § 90.314 Analyzer accuracy and specifications.

(a) *Measurement and accuracy—general.* The analyzers must have a measuring range which allows them to measure the concentrations of the ex-

haust gas sample pollutants with the accuracies shown in Table 2 in Appendix A of this subpart.

(1) *Precision.* The precision of the analyzer must be, at worst, two percent of full-scale concentration for each range used. The precision is defined as 2.5 times the standard deviation(s) of 10 repetitive responses to a given calibration or span gas.

(2) *Noise.* The analyzer peak-to-peak response to zero and calibration or span gases over any 10-second period must not exceed two percent of full-scale chart deflection on all ranges used.

(3) *Zero drift.* The analyzer zero-response drift during a one-hour period must be less than two percent of full-scale chart deflection on the lowest range used. The zero-response is defined as the mean response including noise to a zero-gas during a 30-second time interval.

(4) *Span drift.* The analyzer span drift during a one-hour period must be less than two percent of full-scale chart deflection on the lowest range used. The analyzer span is defined as the difference between the span-response and the zero-response. The span-response is defined as the mean response including noise to a span gas during a 30-second time interval.

(b) *Operating procedure for analyzers and sampling system.* Follow the start-up and operating instructions of the instrument manufacturer or use good engineering practice. Adhere to the minimum requirements given in §§ 90.316 through 90.325 and § 90.409.

(c) *Emission measurement accuracy—Bag sampling.* (1) Good engineering practice dictates that exhaust emission sample analyzer readings below 15 percent of full-scale chart deflection should generally not be used.

(2) Some high resolution read-out systems, such as computers, data loggers, and so forth, can provide sufficient accuracy and resolution below 15 percent of full scale. Such systems may be used provided that additional calibrations are made to ensure the accuracy of the calibration curves. The following procedure for calibration below 15 percent of full scale may be used:

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NOTE TO PARAGRAPH (c): If a gas divider is used, the gas divider must conform to the accuracy requirements as follows. The use of precision blending devices (gas dividers) to obtain the required calibration gas concentrations is acceptable, provided that the blended gases are accurate to within  $\pm 1.5$  percent of NIST gas standards or other gas standards which have been approved by the Administrator. This accuracy implies that primary gases used for blending must be "named" to an accuracy of at least  $\pm 1$  percent, traceable to NIST or other approved gas standards.

(i) Span the full analyzer range using a top range calibration gas. The span gases must be accurate to within  $\pm 2$  percent of NIST gas standards or other gas standards which have been approved by the Administrator.

(ii) Generate a calibration curve according to, and meeting the requirements, of the sections describing analyzer calibrations which are found in §§ 90.316, 90.317, 90.318, and 90.320.

(iii) Select a calibration gas (a span gas may be used for calibrating the CO<sub>2</sub> analyzer) with a concentration between the two lowest non-zero gas divider increments. This gas must be "named" to an accuracy of  $\pm 1$  percent of NIST gas standards or other standards approved by the Administrator.

(iv) Using the calibration curve fitted to the points generated in paragraphs (c)(2) (i) and (ii) of this section, check the concentration of the gas selected in paragraph (c)(2)(iii) of this section. The concentration derived from the curve must be within  $\pm 2.3$  percent ( $\pm 2.8$  percent for CO<sub>2</sub> span gas) of the gas's original named concentration.

(v) Provided the requirements of paragraph (c)(2)(iv) of this section are met, use the gas divider with the gas selected in paragraph (c)(2)(iii) of this section and determine the remainder of the calibration points. Fit a calibration curve per §§ 90.316, 90.317, 90.318, and 90.320 of this chapter for the entire analyzer range.

(d) *Emission measurement accuracy—continuous sampling.* Analyzers used for continuous analysis must be operated such that the measured concentration falls between 15 and 100 percent of full-scale chart deflection. Exceptions to these limits are:

(1) The analyzer's response may be less than 15 percent or more than 100 percent of full scale if automatic range

change circuitry is used and the limits for range changes are between 15 and 100 percent of full-scale chart deflection;

(2) The analyzer's response may be less than 15 percent of full scale if:

(i) The alternative in paragraph (c)(2) of this section is used to ensure that the accuracy of the calibration curve is maintained below 15 percent; or

(ii) The full-scale value of the range is 155 ppm (C) or less; or

(iii) The emissions from the engine are erratic and the integrated chart deflection value for the cycle is greater than 15 percent of full scale; or

(iv) The contribution of all data read below the 15 percent level is less than 10 percent by mass of the final test results.

## § 90.315 Analyzer initial calibration.

(a) *Warming-up time.* The warming-up time should be according to the recommendations of the manufacturer. If not specified, a minimum of two hours should be allowed for warming up the analyzers.

(b) *NDIR, FID, and HFID analyzer.* Tune and maintain the NDIR analyzer per the instrument manufacturer recommendations or specifications or using good engineering practice. The combustion flame of the FID or HFID analyzer must be optimized in order to meet the specifications in § 90.316(b).

(c) *Zero setting and calibration.* Using purified synthetic air (or nitrogen), set the CO, CO<sub>2</sub>, NO<sub>x</sub>, and HC analyzers at zero. Connect the appropriate calibrating gases to the analyzers and record the values. Use the same gas flow rates and pressure as when sampling exhaust.

(d) *Rechecking of zero setting.* Recheck the zero setting and, if necessary, repeat the procedure described in paragraph (c) of this section.

## § 90.316 Hydrocarbon analyzer calibration.

(a) Calibrate the FID and HFID hydrocarbon analyzer as described in this section. Operate the HFID to a set point  $\pm 5.5$  °C between 185 and 197 °C.

(b) *Initial and periodic optimization of detector response.* Prior to initial use and at least annually thereafter, adjust

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the FID and HFID hydrocarbon analyzer for optimum hydrocarbon response as specified in this paragraph. Alternative methods yielding equivalent results may be used, if approved in advance by the Administrator.

(1) Follow good engineering practices for initial instrument start-up and basic operating adjustment using the appropriate fuel (see § 90.312) and purified synthetic air or zero-grade nitrogen.

(2) Use of one of the following procedures is required for FID or HFID optimization:

(i) The procedure outlined in Society of Automotive Engineers (SAE) paper No. 770141, "Optimization of a Flame Ionization Detector for Determination of Hydrocarbon in Diluted Automotive Exhausts;" author, Glenn D. Reschke. This procedure has been incorporated by reference. See § 90.7.

(ii) The HFID optimization procedures outlined in § 86.331-79 of this chapter.

(iii) Alternative procedures may be used if approved in advance by the Administrator.

Example calibration points (%)	Acceptable for calibration?
20, 30, 40, 50, 60, 70 .....	No, range covered is 50 percent, not 64.
20, 30, 40, 50, 60, 70, 80, 90 .....	Yes.
10, 25, 40, 55, 70, 85 .....	Yes.
10, 30, 50, 70, 90 .....	No, though equally spaced and entire range covered, a minimum of six points are needed.

For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, calculate concentration values by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

(d) *Oxygen interference optimization.* Prior to initial use and monthly thereafter, perform the oxygen interference optimization as described in this paragraph. Choose a range where the oxygen interference check gases will fall in the upper 50 percent. Conduct the test, as outlined in this paragraph, with the oven temperature set as required by the instrument manufac-

(3) After the optimum flow rates have been determined, record them for future reference.

(c) *Initial and periodic calibration.* Prior to initial use and monthly thereafter, or within one month prior to the certification test, the FID or HFID hydrocarbon analyzer must be calibrated on all normally used instrument ranges using the steps in this paragraph. Use the same flow rate and pressures as when analyzing samples. Introduce calibration gases directly at the analyzer. An optional method for dilute sampling described in § 86.1310-90(b)(3)(i) may be used.

(1) Adjust analyzer to optimize performance.

(2) Zero the hydrocarbon analyzer with purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each used operating range with calibration gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 range (64 percent) is required (see following table).

Example calibration points (%)	Acceptable for calibration?
20, 30, 40, 50, 60, 70 .....	No, range covered is 50 percent, not 64.
20, 30, 40, 50, 60, 70, 80, 90 .....	Yes.
10, 25, 40, 55, 70, 85 .....	Yes.
10, 30, 50, 70, 90 .....	No, though equally spaced and entire range covered, a minimum of six points are needed.

turer. Oxygen interference check gas specifications are found in § 90.312(d).

(1) Zero the analyzer.

(2) Span the analyzer with the 21 percent oxygen blend.

(3) Recheck zero response. If it has changed more than 0.5 percent of full scale repeat paragraphs (d)(1) and (d)(2) of this section to correct the problem.

(4) Introduce the five percent and 10 percent oxygen interference check gases.

(5) Recheck the zero response. If it has changed by more than  $\pm$  one percent of full scale, repeat the test.

(6) Calculate the percent of oxygen interference (designated as percent O<sub>2</sub>I) for each mixture in paragraph (d)(4) of this section according to the following equation.

$$\text{Percent O}_2\text{I} = \frac{\text{B} - \text{Analyzer response (ppmC)}}{\text{B}} (100)$$

$$\text{Analyzer response} = \left( \frac{\text{A}}{\% \text{ of full-scale analyzer response due to A}} \right) \times (\% \text{ of full-scale analyzer response due to B})$$

Where:

A = hydrocarbon concentration (ppmC) of the span gas used in paragraph (d)(2) of this section.

B = hydrocarbon concentration (ppmC) of the oxygen interference check gases used in paragraph (d)(4) of this section.

(7) The percent of oxygen interference (designated as percent O<sub>2</sub> I) must be less than  $\pm$  three percent for all required oxygen interference check gases prior to testing.

(8) If the oxygen interference is greater than the specifications, incrementally adjust the air flow above and below the manufacturer's specifications, repeating paragraphs (d)(1) through (d)(7) of this section for each flow.

(9) If the oxygen interference is greater than the specification after adjusting the air flow, vary the fuel flow and thereafter the sample flow, repeating paragraphs (d)(1) through (d)(7) of this section for each new setting.

(10) If the oxygen interference is still greater than the specifications, repair or replace the analyzer, FID fuel, or burner air prior to testing. Repeat this section with the repaired or replaced equipment or gases.

#### **§ 90.317 Carbon monoxide analyzer calibration.**

(a) Calibrate the NDIR carbon monoxide analyzer as described in this section.

(b) *Initial and periodic interference.* Prior to its initial use and annually

thereafter, check the NDIR carbon monoxide analyzer for response to water vapor and CO<sub>2</sub>.

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance on the most sensitive range to be used.

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

(3) Bubble a mixture of three percent CO<sub>2</sub> in N<sub>2</sub> through water at room temperature and record analyzer response.

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

(c) *Initial and periodic calibration.* Prior to its initial use and monthly thereafter, or within one month prior to the certification test, calibrate the NDIR carbon monoxide analyzer.

(1) Adjust the analyzer to optimize performance.

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

(3) Calibrate on each used operating range with carbon monoxide-in-N<sub>2</sub> calibration gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 range (64 percent) is required (see following table).

Example calibration points (%)	Acceptable for calibration?
20, 30, 40, 50, 60, 70 .....	No, range covered is 50 percent, not 64.
20, 30, 40, 50, 60, 70, 80, 90 .....	Yes.
10, 25, 40, 55, 70, 85 .....	Yes.

Example calibration points (%)	Acceptable for calibration?
10, 30, 50, 70, 90 .....	No, though equally spaced and entire range covered, a minimum of six points are needed.

Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, calculate concentration values by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

#### § 90.318 Oxides of nitrogen analyzer calibration.

(a) Calibrate the chemiluminescent oxides of nitrogen analyzer as described in this section.

(b) *Initial and Periodic Interference.* Prior to its initial use and monthly thereafter, or within one month prior to the certification test, check the chemiluminescent oxides of nitrogen analyzer for NO<sub>2</sub> to NO converter efficiency. Figure 1 in Appendix B of this subpart is a reference for paragraphs (b)(1) through (11) of this section:

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance.

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

(3) Connect the outlet of the NO<sub>x</sub> 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<sub>x</sub> generator analyzer-system an NO-in-nitrogen (N<sub>2</sub>) mixture with an NO concentration equal to approximately 80 percent of the most common operating range. The NO<sub>2</sub> content of the gas mixture must be less than five percent 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<sub>x</sub> generator O<sub>2</sub> (or air) supply and adjust the O<sub>2</sub> (or air) flow rate so that the NO indicated by

the analyzer is about 10 percent less than indicated in paragraph (b)(5) of this section. Record the concentration of NO in this NO+O<sub>2</sub> mixture as value "c."

(7) Switch the NO<sub>x</sub> generator to the generation mode and adjust the generation rate so that the NO measured on the analyzer is 20 percent of that measured in paragraph (b)(5) of this section. There must be at least 10 percent unreacted NO at this point. Record the concentration of residual NO as value "d."

(8) Switch the oxides of nitrogen analyzer to the NO<sub>x</sub> mode and measure total NO<sub>x</sub>. Record this value as "a."

(9) Switch off the NO<sub>x</sub> generator but maintain gas flow through the system. The oxides of nitrogen analyzer will indicate the NO<sub>x</sub> in the NO+O<sub>2</sub> mixture. Record this value as "b".

(10) Turn off the NO<sub>x</sub> generator O<sub>2</sub> (or air) supply. The analyzer will now indicate the NO<sub>x</sub> in the original NO-in-N<sub>2</sub> mixture. This value should be no more than five percent above the value indicated in paragraph (b)(4) of this section.

(11) Calculate the efficiency of the NO<sub>x</sub> converter by substituting the concentrations obtained into the following equation:

$$\text{percent efficiency} = \left( 1 + \frac{a - b}{c - d} \right) \times 100$$

Where:

a = concentration obtained in paragraph (b)(8),

b = concentration obtained in paragraph (b)(9),

c = concentration obtained in paragraph (b)(6),

d = concentration obtained in paragraph (b)(7).

If converter efficiency is less than 90 percent, corrective action will be required.

(c) *Initial and periodic calibration.* Prior to its initial use and monthly thereafter, or within one month prior to the certification test, calibrate the chemiluminescent oxides of nitrogen

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analyzer 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 purified synthetic air or zero-grade nitrogen.

Example calibration points (%)	Acceptable for calibration?
20, 30, 40, 50, 60, 70 .....	No, range covered is 50 percent, not 64
20, 30, 40, 50, 60, 70, 80, 90 .....	Yes.
10, 25, 40, 55, 70, 85 .....	Yes.
10, 30, 50, 70, 90 .....	No, though equally spaced and entire range covered, a minimum of six points are needed.

Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, calculate concentration values by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

(d) The initial and periodic interference, system check, and calibration test procedures specified in §86.332-79 of this chapter may be used in lieu of the procedures specified in this section.

**§ 90.319 NO<sub>x</sub> converter check.**

(a) The efficiency of the converter used for the conversion of NO<sub>2</sub> to NO is tested as given in paragraphs (a)(1) through (a)(8) of this section.

(1) Using the test setup as shown in Figure 1 in Appendix B of this subpart (see also §90.318 of this chapter) and the procedure described in paragraphs (a)(2) through (a)(8) of this section, test the efficiency of converters by means of an ozonator.

(2) Calibrate the HCLD or CLD in the most common operating range following the manufacturer's specifications using zero and span gas (the NO content of which must amount to about 80 percent of the operating range and the NO<sub>2</sub> concentration of the gas mixture less than five percent of the NO concentration). The NO<sub>x</sub> analyzer must be in the NO mode so that the span gas does not pass through the con-

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(3) Calibrate on each normally used operating range with NO-in-N<sub>2</sub> calibration gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 range (64 percent) is required (see following table).

Example calibration points (%)	Acceptable for calibration?
20, 30, 40, 50, 60, 70 .....	No, range covered is 50 percent, not 64
20, 30, 40, 50, 60, 70, 80, 90 .....	Yes.
10, 25, 40, 55, 70, 85 .....	Yes.

verter. Record the indicated concentration.

(3) Calculate the efficiency of the NO<sub>x</sub> converter as described in §90.318(b).

(4) Via a T-fitting, add oxygen continuously to the gas flow until the concentration indicated is about 20 percent less than the indicated calibration concentration given in paragraph (a)(2) of this section. Record the indicated concentration "c." The ozonator is kept deactivated throughout the process.

(5) Activate the ozonator to generate enough ozone to bring the NO concentration down to about 20 percent (minimum 10 percent) of the calibration concentration given in paragraph (a)(2) of this section. Record the indicated concentration "d."

NOTE: If, with the analyzer in the most common range, the NO<sub>x</sub> converter can not give a reduction from 80 percent to 20 percent, then use the highest range which will give the reduction.

(6) Switch the NO analyzer to the NO<sub>x</sub> mode which means that the gas mixture (consisting of NO, NO<sub>2</sub>, O<sub>2</sub> and N<sub>2</sub>) now passes through the converter. Record the indicated concentration "a."

(7) Deactivate the ozonator. The mixture of gases described in paragraph (a)(6) of this section passes through the converter into the detector. Record the indicated concentration "b."

(8) Switched to NO mode with the ozonator deactivated, the flow of oxygen or purified synthetic air is also

shut off. The NO<sub>x</sub> reading of the analyzer may not deviate by more than ± five percent of the theoretical value of the figure given in paragraph (a)(2) of this section.

(b) The efficiency of the converter must be tested prior to each calibration of the NO<sub>x</sub> analyzer.

(c) The efficiency of the converter may not be less than 90 percent.

#### **§ 90.320 Carbon dioxide analyzer calibration.**

(a) Prior to its initial use and monthly thereafter, or within one month prior to the certification test, calibrate the NDIR carbon dioxide analyzer as follows:

Example calibration points (%)	Acceptable for Calibration?
20, 30, 40, 50, 60, 70 .....	No, range covered is 50 percent, not 64.
20, 30, 40, 50, 60, 70, 80, 90 .....	Yes.
10, 25, 40, 55, 70, 85 .....	Yes.
10, 30, 50, 70, 90 .....	No, though equally spaced and entire range covered, a minimum of six points are needed.

Additional calibration points may be generated. For each range calibrated, if the deviation from a least-squares best-fit straight line is two percent or less of the value at each data point, calculate concentration values by use of a single calibration factor for that range. If the deviation exceeds two percent at any point, use the best-fit non-linear equation which represents the data to within two percent of each test point to determine concentration.

(b) The initial and periodic interference, system check, and calibration test procedures specified in §§ 86.316, 86.319, 86.320, 86.321, and 86.322 of this chapter may be used in lieu of the procedures in this section.

#### **§ 90.321 NDIR analyzer calibration.**

(a) *Detector optimization.* If necessary, follow the instrument manufacturer's

(1) Follow good engineering practices for instrument start-up and operation. Adjust the analyzer to optimize performance.

(2) Zero the carbon dioxide analyzer with either purified synthetic air or zero-grade nitrogen.

(3) Calibrate on each normally used operating range with carbon dioxide-in-N<sub>2</sub> calibration or span gases having nominal concentrations between 10 and 90 percent of that range. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 range (64 percent) is required (see following table).

instructions for initial start-up and basic operating adjustments.

(b) *Calibration curve.* Develop a calibration curve for each range used as follows:

(1) Zero the analyzer.

(2) Span the analyzer to give a response of approximately 90 percent of full-scale chart deflection.

(3) Recheck the zero response. If it has changed more than 0.5 percent of full scale, repeat the steps given in paragraphs (b)(1) and (b)(2) of this section.

(4) Record the response of calibration gases having nominal concentrations between 10 and 90 percent of full-scale concentration. A minimum of six evenly spaced points covering at least 80 percent of the 10 to 90 range (64 percent) is required (see following table).

Example calibration points (%)	Acceptable for calibration?
20, 30, 40, 50, 60, 70 .....	No, range covered is 50 percent, not 64.
20, 30, 40, 50, 60, 70, 80, 90 .....	Yes.
10, 25, 40, 55, 70, 85 .....	Yes.
10, 30, 50, 70, 90 .....	No, though equally spaced and entire range covered, a minimum of six points are needed.

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(5) Generate a calibration curve. The calibration curve must be of fourth order or less, have five or fewer coefficients, and be of the form of the following equation (1) or (2). Include zero as a data point. Compensation for known impurities in the zero gas can be made to the zero-data point. The calibration curve must fit the data points within two percent of point or one percent of full scale, whichever is less.

$$y = Ax^4 + Bx^3 + Cx^2 + Dx + E \quad (1)$$

$$y = \frac{x}{Ax^4 + Bx^3 + Cx^2 + Dx + E} \quad (2)$$

where:

y = concentration

x = chart deflection

(6) Option. A new calibration curve need not be generated if:

(i) A calibration curve conforming to paragraph (b)(5) of this section exists; or,

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(ii) The responses generated in paragraph (b)(4) of this section are within one percent of full scale or two percent of point, whichever is less, of the responses predicted by the calibration curve for the gases used in paragraph (b)(4) of this section.

(7) If multiple range analyzers are used, the lowest range used must meet the curve fit requirements below 15 percent of full scale.

(c) *Linear calibration criteria.* If any range is within two percent of being linear, a linear calibration may be used. To determine if this criterion is met:

(1) Perform a linear least-square regression on the data generated. Use an equation of the form  $y=mx$ , where x is the actual chart deflection and y is the concentration.

(2) Use the equation  $z=y/m$  to find the linear chart deflection (designated as z) for each calibration gas concentration (designated as y).

(3) Determine the linearity (designated as percent L) for each calibration gas by:

$$\% L = \frac{(z - x)}{\text{Full-scale linear chart deflection}} \times (100)$$

(4) The linearity criterion is met if the %L is less than  $\pm$  two percent for each data point generated. For each emission test, use a calibration curve of the form  $Y=mx$ . The slope (designated as m) is defined for each range by the spanning process.

### § 90.322 Calibration of other equipment.

Calibrate other test equipment used for testing as often as required by the test equipment manufacturer or as necessary according to good engineering practice.

### § 90.323 Analyzer bench checks.

(a) Prior to initial use and after major repairs, verify that each analyzer complies with the specifications given in Table 2 in Appendix A of this part.

(b) If a stainless steel NO<sub>2</sub> to NO converter is used, condition all new or replacement converters. The conditioning consists of either purging the converter with air for a minimum of four hours or until the converter efficiency is greater than 90 percent. The converter must be at operational temperature while purging. Do not use this procedure prior to checking converter efficiency on in-use converters.

### § 90.324 Analyzer leakage check.

(a) *Vacuum side leak check.* (1) Check any location within the analysis system where a vacuum leak could affect the test results.

(2) The maximum allowable leakage rate on the vacuum side is 0.5 percent of the in-use flow rate for the portion of the system being checked. The analyzer flows and bypass flows may be used to estimate the in-use flow rates.

(3) The sample probe and the connection between the sample probe and valve V2, see Figure 2 in Appendix B of this subpart, may be excluded from the leak check.

(b) *Pressure side leak check.* The maximum allowable leakage rate on the pressure side is five percent of the in-use flow rate.

#### **§ 90.325 Analyzer interference checks.**

(a) Gases present in the exhaust other than the one being analyzed can interfere with the reading in several ways. Positive interference occurs in NDIR and PMD instruments when the interfering gas gives the same effect as the gas being measured, but to a lesser degree. Negative interference occurs in NDIR instruments by the interfering gas broadening the absorption band of the measured gas, and in CLD instruments by the interfering gas quenching the radiation. The interference checks described in this section are to be made initially and after any major repairs that could affect analyzer performance.

(b) *CO analyzer water and CO<sub>2</sub> interference checks.* Bubble through water at room temperature a CO<sub>2</sub> span gas having a concentration of between 80 percent and 100 percent inclusive of full scale of the maximum operating range used during testing and record the ana-

lyzer response. For dry measurements, this mixture may be introduced into the sample system prior to the water trap. The analyzer response must not be more than one percent of full scale for ranges equal to or above 300 ppm or more than three ppm for ranges below 300 ppm.

(c) NO<sub>x</sub> analyzer quench check. The two gases of concern for CLD (and HCLD) analyzers are CO<sub>2</sub> and water vapor. Quench responses to these two gases are proportional to their concentrations and, therefore, require test techniques to determine quench at the highest expected concentrations experienced during testing.

(1) *NO<sub>x</sub> analyzer CO<sub>2</sub> quench check.* (i) Pass a CO<sub>2</sub> span gas having a concentration of 80 percent to 100 percent of full scale of the maximum operating range used during testing through the CO<sub>2</sub> NDIR analyzer and record the value "a."

(ii) Dilute the CO<sub>2</sub> span gas approximately 50 percent with NO span gas and pass through the CO<sub>2</sub> NDIR and CLD (or HCLD). Record the CO<sub>2</sub> and NO values as "b" and "c" respectively.

(iii) Shut off the CO<sub>2</sub> and pass only the NO span gas through the CLD (or HCLD). Record the NO value as "d."

(iv) Calculate the percent CO<sub>2</sub> quench as follows, not to exceed three percent:

$$\% \text{ CO}_2 \text{ quench} = 100 \times \left( 1 - \frac{(c \times a)}{(d \times a) - (d \times b)} \right) \times (a/b)$$

Where:

a = Undiluted CO<sub>2</sub> concentration (percent)

b = Diluted CO<sub>2</sub> concentration (percent)

c = Diluted NO concentration (ppm)

d = Undiluted NO concentration (ppm)

(2) *NO<sub>x</sub> analyzer water quench check.*

(i) This check applies to wet measurements only. An NO span gas having a concentration of 80 percent to 100 percent of full scale of a normal operating range is passed through the CLD (or HCLD) and the response recorded as "D". The NO span gas is then bubbled through water at room temperature and passed through the CLD (or HCLD) and the analyzer's response recorded as

AR. Determine and record the analyzer's absolute operating pressure and the bubbler water temperature. (It is important that the NO span gas contains minimal NO<sub>2</sub> concentration for this check. No allowance for absorption of NO<sub>2</sub> in water has been made in the following quench calculations.)

(ii) Calculations for water quench must consider dilution of the NO span gas with water vapor and scaling of the water vapor concentration of the mixture to that expected during testing. Determine the mixture's saturated vapor pressure (designated as P<sub>wb</sub>) that corresponds to the bubbler water

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temperature. Calculate the water concentration ("Z1", percent) in the mixture by the following equation:

$$Z1 = 100 \times \frac{Pwb}{GP}$$

where GP is the analyzer's standard operating pressure (pascals).

(iii) Calculate the expected dilute NO span gas and water vapor mixture concentration (designated as D1) by the following equation:

$$D1 = D \times \left( 1 - \frac{Z1}{100} \right)$$

### § 90.326 Pre- and post-test analyzer calibration.

Calibrate the range of each analyzer used during the engine exhaust emission test prior to and after each test in accordance with the following:

(a) Make the calibration by using a zero gas and a span gas. The span gas value must be between 75 percent and 100 percent of full scale, inclusive, of the measuring range.

(b) Use the same analyzer(s) flow rate and pressure as that used during exhaust emission test sampling.

(c) Warm-up and stabilize the analyzer(s) before the calibration is made.

(d) If necessary clean and/or replace filter elements before calibration is made.

(e) Calibrate analyzer(s) as follows:

(1) Zero the analyzer using the appropriate zero gas. Adjust analyzer zero if necessary. Zero reading should be stable.

(2) Span the analyzer using the appropriate span gas for the range being calibrated. Adjust the analyzer to the calibration set point if necessary.

(3) Re-check zero and span set points.

(4) If the response of the zero gas or span gas differs more than one percent of full scale, then repeat paragraphs (e) (1) through (3) of this section.

### § 90.327 Sampling system requirements.

(a) *Sample component surface temperature.* For sampling systems which use heated components, use engineering judgment to locate the coolest portion of each component (pump, sample line

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section, filters, and so forth) in the heated portion of the sampling system that has a separate source of power or heating element. Monitor the temperature at that location. If several components are within an oven, then only the surface temperature of the component with the largest thermal mass and the oven temperature need be measured.

(b) If water is removed by condensation, monitor the sample gas temperature or sample dew point either within the water trap or downstream. It may not exceed 7 °C.

### § 90.328 Measurement equipment accuracy/calibration frequency table.

(a) The accuracy of measurements must be such that the maximum tolerances shown in Table 2 in Appendix A of this subpart are not exceeded.

(b) All equipment and analyzers must be calibrated according to the frequencies shown in Table 2 in Appendix A of this subpart.

(c) Prior to initial use and after major repairs, bench check each analyzer (see § 90.323).

(d) Calibrate equipment as specified in § 90.306 and §§ 90.315 through 90.322.

(e) At least monthly, or after any maintenance which could alter calibration, perform the following calibrations and checks.

(1) Leak check the vacuum side of the system (see § 90.324(a)).

(2) Verify that the automatic data collection system (if used) meets the requirements found in Table 2 in Appendix A of this subpart.

(3) Check the fuel flow measurement instrument to insure that the specifications in Table 2 in Appendix A of this subpart are met.

(f) Verify that all NDIR analyzers meet the water rejection ratio and the CO<sub>2</sub> rejection ratio as specified in § 90.325.

(g) Verify that the dynamometer test stand and power output instrumentation meet the specifications in Table 2 in Appendix A of this subpart.

### § 90.329 Catalyst thermal stress test.

(a) *Oven characteristics.* The oven used for thermally stressing the test catalyst must be capable of maintaining a temperature of 500 ± 5 °C and 1000 ± 10 °C.

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(b) *Evaluation gas composition.* (1) A synthetic exhaust gas mixture is used for evaluating the effect of thermal stress on catalyst conversion efficiency.

(2) The synthetic exhaust gas mixture must have the following composition:

Constituent	Volume percent	Parts per million
Carbon Monoxide .....	1 .....	.....
Oxygen .....	1.3 .....	.....
Carbon Dioxide .....	3.8 .....	.....
Water Vapor .....	10 .....	.....

Constituent	Volume percent	Parts per million
Sulfur dioxide .....	.....	20
Oxides of nitrogen .....	.....	280
Hydrogen .....	.....	3500
Hydrocarbon* .....	.....	4000
Nitrogen = Balance		

\* Propylene/propane ratio = 2/1.

(c) *Phase 2 engines.* The catalyst thermal stress test is not required for engine families certified to the Phase 2 standards.

[60 FR 34598, July 3, 1995, as amended at 64 FR 15243, Mar. 30, 1999]

## APPENDIX A TO SUBPART D OF PART 90—TABLES

TABLE 1—SYMBOLS USED IN SUBPART D

Symbol	Term	Unit
CO	Carbon monoxide.	
CO <sub>2</sub>	Carbon dioxide.	
NO	Nitric oxide.	
NO <sub>2</sub>	Nitrogen dioxide.	
NO <sub>X</sub>	Oxides of nitrogen.	
O <sub>2</sub>	Oxygen.	
conc	Concentration (ppm by volume) .....	ppm
f	Engine specific parameter considering atmospheric conditions.	
F <sub>FCB</sub>	Fuel specific factor for the carbon balance calculation.	
F <sub>FD</sub>	Fuel specific factor for exhaust flow calculation on dry basis.	
F <sub>FH</sub>	Fuel specific factor representing the hydrogen to carbon ratio.	
F <sub>FW</sub>	Fuel specific factor for exhaust flow calculation on wet basis.	
G <sub>AIRW</sub>	Intake air mass flow rate on wet basis .....	kg/h
G <sub>AIRD</sub>	Intake air mass flow rate on dry basis .....	kg/h
G <sub>EXHW</sub>	Exhaust gas mass flow rate on wet basis .....	kg/h
G <sub>Fuel</sub>	Fuel mass flow rate .....	kg/h
H	Absolute humidity (water content related to dry air) .....	gr/kg
i	Subscript denoting an individual mode.	
K <sub>H</sub>	Humidity correction factor.	
L	Percent torque related to maximum torque for the test mode .....	percent
mass	Pollutant mass flow .....	g/h
n <sub>d,i</sub>	Engine speed (average at the i'th mode during the cycle) .....	1/min
P <sub>s</sub>	Dry atmospheric pressure .....	kPa
P <sub>d</sub>	Test ambient saturation vapor pressure at ambient temperature .....	kPa
P	Gross power output uncorrected .....	kW
P <sub>AUX</sub>	Declared total power absorbed by auxiliaries fitted for the test .....	kW
P <sub>M</sub>	Maximum power measured at the test speed under test conditions .....	kW
P <sub>i</sub>	P <sub>i</sub> = P <sub>M,i</sub> + P <sub>AUX,i</sub>	
P <sub>B</sub>	Total barometric pressure (average of the pre-test and post-test values) .....	kPa
R <sub>a</sub>	Relative humidity of the ambient air .....	percent
T	Absolute temperature at air inlet .....	C
T <sub>be</sub>	Air temperature after the charge air cooler (if applicable) (average) .....	C
T <sub>clout</sub>	Coolant temperature outlet (average) .....	C
T <sub>dd</sub>	Absolute dew point temperature .....	C
T <sub>d,i</sub>	Torque (average at the i'th mode during the cycle) .....	N·m
T <sub>SC</sub>	Temperature of the intercooled air .....	C
T <sub>ref</sub>	Reference temperature .....	C
V <sub>EXHD</sub>	Exhaust gas volume flow rate on dry basis .....	m <sup>3</sup> /h
V <sub>AIRW</sub>	Intake air volume flow rate on wet basis .....	m <sup>3</sup> /h
P <sub>B</sub>	Total barometric pressure .....	kPa
V <sub>EXHW</sub>	Exhaust gas volume flow rate on wet basis .....	m <sup>3</sup> /h
WF	Weighing factor.	
WF <sub>E</sub>	Effective weighing factor.	

TABLE 2—MEASUREMENT CALIBRATION ACCURACY AND FREQUENCY

No.	Item	Permissible deviation from reading*		Calibration frequency
		Non-idle	Idle	
1 ...	Engine speed .....	± 2 % .....	Same .....	Monthly or within one month prior to the certification test.
2 ...	Torque .....	± 2 % .....	.....	Monthly or within one month prior to the certification test.
3 ...	Fuel consumption .....	± 2 % .....	±5% .....	Monthly or within one month prior to the certification test.
4 ...	Air consumption .....	± 2 % .....	±5% .....	As required.
5 ...	Coolant temperature .....	± 2 °C .....	Same .....	As required.
6 ...	Lubricant temperature .....	± 2 °C .....	Same .....	As required.
7 ...	Exhaust back pressure .....	± 5 % .....	Same .....	As required.
8 ...	Inlet depression .....	± 5 % .....	Same .....	As required.
9 ...	Exhaust gas temperature .....	± 15 °C .....	Same .....	As required.
10	Air inlet temperature (combustion air) ..	± 2 °C .....	Same .....	As required.
11	Atmospheric pressure .....	± 0.5 % .....	Same .....	As required.
12	Humidity (combustion air) (relative) .....	± 3.0 % .....	Same .....	As required.
13	Fuel temperature .....	± 2 °C .....	Same .....	As required.
14	Temperature with regard to dilution system.	± 2 °C .....	Same .....	As required.
15	Dilution air humidity .....	± 3 % absolute .....	Same .....	As required.
16	HC analyzer .....	± 2 %** .....	Same .....	Monthly or within one month prior to the certification test.
17	CO analyzer .....	± 2 %** .....	Same .....	Monthly or within one month prior to the certification test.
18	NO <sub>x</sub> analyzer .....	± 2 %** .....	Same .....	Monthly or within one month prior to the certification test.
19	NO <sub>x</sub> converter check .....	90 % .....	Same .....	Monthly or within one month prior to the certification test.
20	CO <sub>2</sub> analyzer .....	± 2 %** .....	Same .....	Monthly or within one month prior to the certification test.

\* All accuracy requirements pertain to the final recorded value which is inclusive of the data acquisition system.

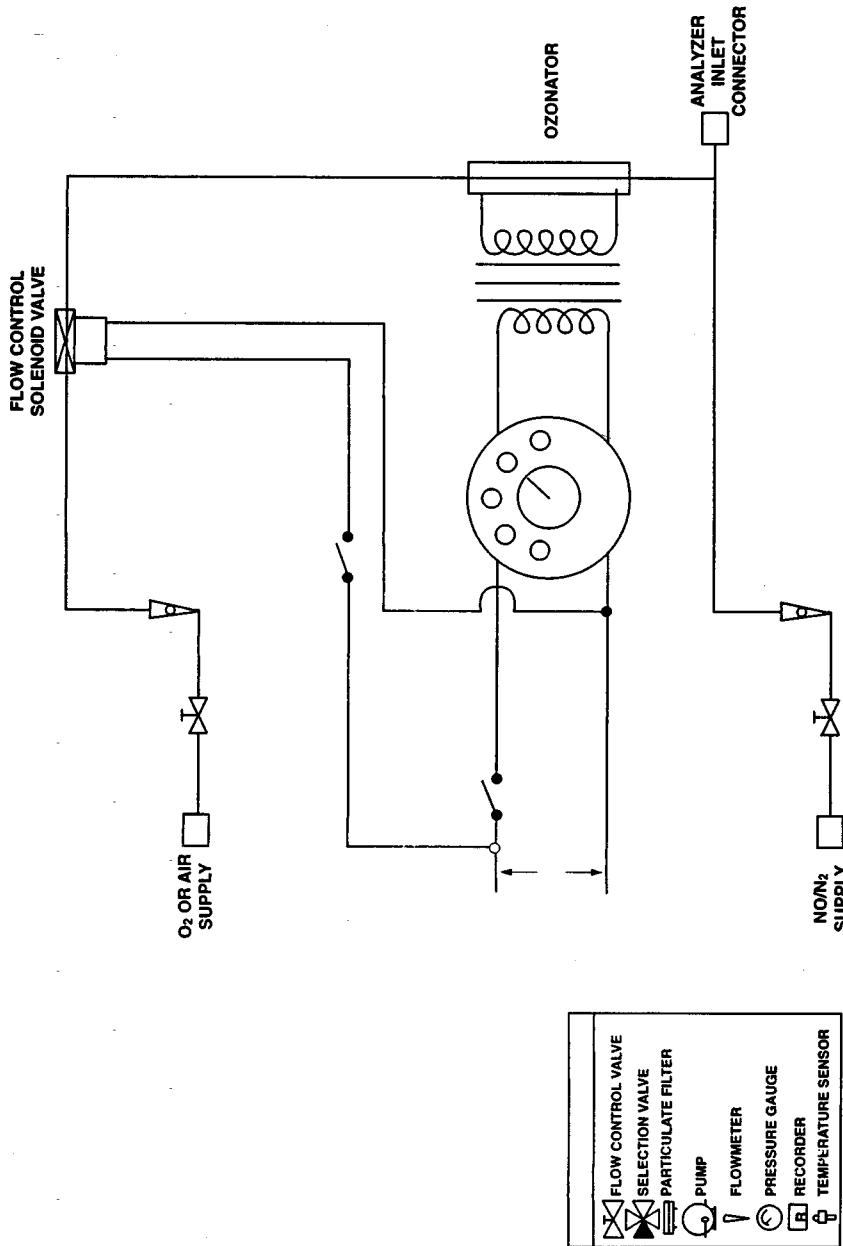
\*\* If reading is under 100 ppm then the accuracy shall be ± 2 ppm.

TABLE 3—TEST FUEL SPECIFICATIONS

Item	Property	Tolerances	Procedure (ASTM) <sup>1</sup>
Sulfur, ppm max.	339 .....	.....	D 2622-92
Benzene, max. %	1.5 .....	.....	D 3606-92
RVP, psi	8.7 .....	±0.2 .....	D 5191-93a
Octane, R+M/2	87.3 .....	±0.5 .....	D 2699-92
IBP, °C	32.8 .....	±11.0 .....	D 86-93
10 % point, °C	53.3 .....	±5.5 .....	D 86-93
50 % point, °C	103.3 .....	±5.5 .....	D 86-93
90 % point, °C	165.6 .....	±5.5 .....	D 86-93
End Point, max. °C	212.8 .....	.....	D 86-93
Phosphorus, g/liter, max.	0.02 .....	.....	D 3231-89
Lead, g/liter, max.	0.02 .....	.....	.....
Manganese, g/liter, max.	0.004 .....	.....	.....
Aromatics, %	32.0 .....	±4.0 .....	D 1319-89
Olefins, %	9.2 .....	±4.0 .....	D 1319-89
Saturates, %	Remainder .....	.....	D 1319-89

<sup>1</sup> All ASTM procedures in this table have been incorporated by reference. See § 90.7.

## APPENDIX B TO SUBPART D OF PART 90—FIGURES

Figure 1.—NO<sub>x</sub> Converter Efficiency Detector

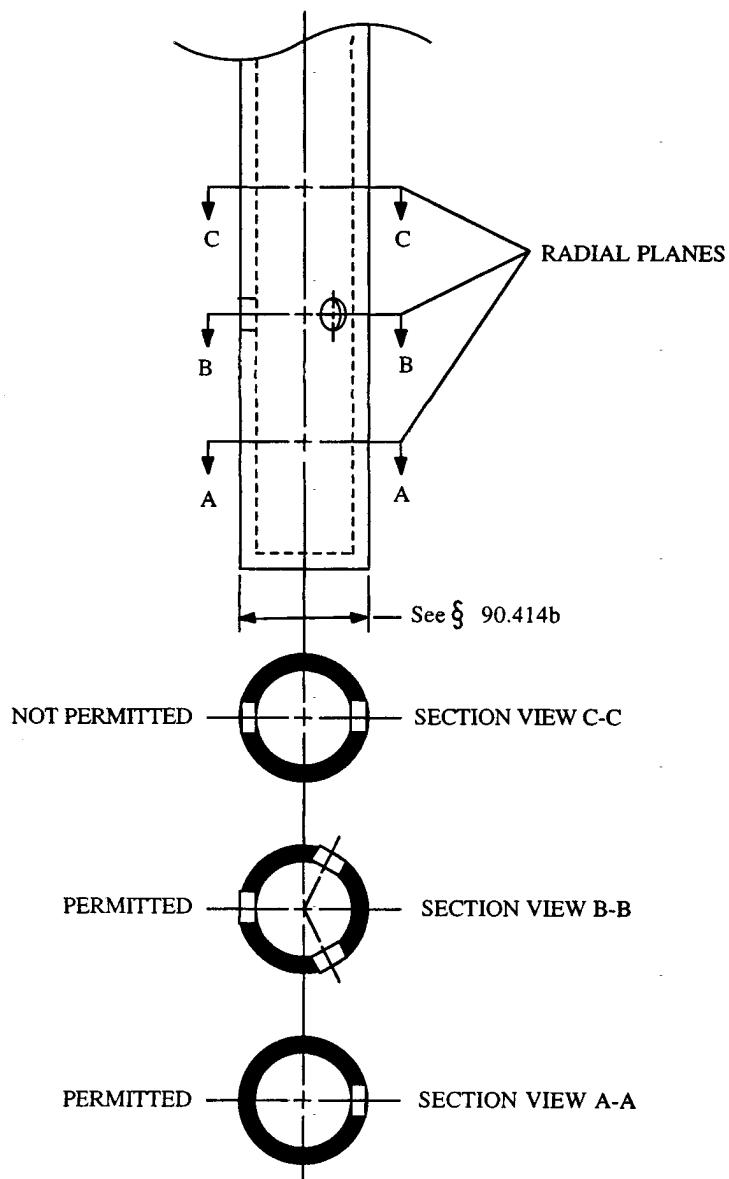


Figure 2.—Sample Probe and Typical Hole Spacings