



IM 240 & Evap Technical Guidance

IM240 & Evap Technical Guidance

Regional & State Programs Division
Office of Mobile Sources
U.S. Environmental Protection Agency

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This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data which are currently available.

The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

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Introduction

This document is the successor to the June 1996 version of "High-Tech I/M Test Procedures, Emission Standards, Quality Control Requirements, and Equipment Specifications." It incorporates changes discussed by EPA and I/M stakeholders since June 1996 and thus includes the latest standards and procedures recommended for IM240 testing. Several major additions and changes have been made. Within this version, some of the technical dynamometer discussion has been moved into the appendices. This new version has also been altered to address issues concerning evap testing, equipment calibrations, and other emission measurement details.

IM240 test locations which already have equipment in-place, as well as those designed to comply with the June 1996 guidance document may continue to use that document as a reference. However, States currently running IM240 test programs may also wish to use specific sections of this version of the IM240 guidance in order to make existing programs more accurate and efficient. IM240 programs which are designed after the publication of the present version of this guidance are also advised to reference this version of the technical guidance.

§85.2205 Test Standards

(a) IM240 Emission Standards

- (1) Two Ways to Pass Standards. If the corrected, composite emission rates calculated in §85.2205(b) exceed the standards for any exhaust component, additional analysis of test results shall look at the second phase of the driving cycle separately. Phase 2 shall include second 94 through second 239. Second-by-second emission rates in grams, and composite emission rates in grams per mile for Phase 2 and for the entire test shall be recorded for each gas. If the composite emission level is equal to or below the composite standard, or if the Phase 2 grams per mile emission level is equal to or below the applicable Phase 2 standard, then the vehicle shall pass the test for that exhaust component.
- (2) Start-up Standards. Start-up standards should be used during the first two years of program operation. Tier 1 standards are recommended for 1996 and newer vehicles and may be used for 1994 and newer vehicles certified to Tier 1 standards as well. The following exhaust emissions standards, in grams per mile, are recommended:

(i) Light Duty Vehicles.

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1996+	0.80	0.50	15.0	12.0	2.0	2.0
1991-1995	1.20	0.75	20.0	16.0	2.5	2.5
1983-1990	2.00	1.25	30.0	24.0	3.0	3.0
1981-1982	2.00	1.25	60.0	48.0	3.0	3.0
1980	2.00	1.25	60.0	48.0	6.0	6.0
1977-1979	7.50	5.00	90.0	72.0	6.0	6.0
1975-1976	7.50	5.00	90.0	72.0	9.0	9.0
1973-1974	10.0	6.00	150	120	9.0	9.0
1968-1972	10.0	6.00	150	120	10.0	10.0

(ii) High-Altitude Light Duty Vehicles.

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1983-1984	2.00	1.25	60.0	48.0	3.0	3.0
1982	2.00	1.25	75.0	60.0	3.0	3.0

(iii) Light Duty Trucks (0 - 6000 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1996+						
(≤3750 LVW)	0.80	0.50	15.0	12.0	2.0	2.0
(>3750 LVW)	1.00	0.63	20.0	16.0	2.5	2.5
1991-1995	2.40	1.50	60.0	48.0	3.0	3.0
1988-1990	3.20	2.00	80.0	64.0	3.5	3.5
1984-1987	3.20	2.00	80.0	64.0	7.0	7.0
1979-1983	7.50	5.00	100	80.0	7.0	7.0

1975-1978	8.00	5.00	120	96.0	9.0	9.0
1973-1974	10.0	6.00	150	120	9.0	9.0
1968-1972	10.0	6.00	150	120	10.0	10.0

(iv) High-Altitude Light Duty Trucks (0 - 6000 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1991+	3.00	2.00	70.0	56.0	3.0	3.0
1988-1990	4.00	2.50	90.0	72.0	3.5	3.5
1984-1987	4.00	2.50	90.0	72.0	7.0	7.0
1982-1983	8.00	5.00	130	104	7.0	7.0

(v) Light Duty Trucks (6001 - 8500 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1996+						
(≤5750 ALVW)	1.00	0.63	20.0	16.0	2.5	2.5
(>5750 ALVW)	2.40	1.50	60.0	48.0	4.0	4.0
1991-1995	2.40	1.50	60.0	48.0	4.5	4.5
1988-1990	3.20	2.00	80.0	64.0	5.0	5.0
1984-1987	3.20	2.00	80.0	64.0	7.0	7.0
1979-1983	7.50	5.00	100	80.0	7.0	7.0
1975-1978	8.00	5.00	120	96.0	9.0	9.0
1973-1974	10.0	6.00	150	120	9.0	9.0
1968-1972	10.0	6.00	150	120	10.0	10.0

(vi) High-Altitude Light Duty Trucks (6001 - 8500 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1991+	3.00	2.00	70.0	56.0	4.5	4.5
1988-1990	4.00	2.50	90.0	72.0	5.0	5.0
1984-1987	4.00	2.50	90.0	72.0	7.0	7.0
1982-1983	8.00	5.00	130	104	7.0	7.0

(vii) Heavy-Duty Trucks (greater than 8500 pounds GVWR).¹

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1998+	2.00	1.30	30.0	24.0	4.0	4.0
1991-1997	3.00	1.90	60.0	48.0	6.0	6.0
1987-1990	3.00	1.90	60.0	48.0	8.0	8.0

¹ The heavy-duty truck standards provided here were calculated using new vehicle certification standards and have not been subjected to field testing. This document provides no other guidance on heavy duty truck testing. Thus, anyone interested in performing IM240 tests on heavy-duty trucks should proceed with appropriate caution.

1985-1986	5.00	3.10	75.0	60.0	8.0	8.0
1979-1984	6.00	3.80	100.0	80.0	8.0	8.0
1974-1978	10.0	6.30	150.0	120.0	10.0	10.0
1970-1973	10.0	6.30	175.0	140.0	10.0	10.0
pre-1970	20.0	12.50	200.0	160.0	15.0	15.0

- (3) Final Standards. The following exhaust emissions standards, in grams per mile, are recommended for vehicles tested in the calendar years 1997 and later. Tier 1 standards are recommended for all 1996 and newer vehicles but may be used for 1994 and newer vehicles.

(i) Light Duty Vehicles.

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1996+	0.60	0.40	10.0	8.0	1.5	1.5
1983-1995	0.80	0.50	15.0	12.0	2.0	2.0
1981-1982	0.80	0.50	30.0	24.0	2.0	2.0
1980	0.80	0.50	30.0	24.0	4.0	4.0
1977-1979	3.00	2.00	65.0	52.0	4.0	4.0
1975-1976	3.00	2.00	65.0	52.0	6.0	6.0
1973-1974	7.00	4.50	120	96.0	6.0	6.0
1968-1972	7.00	4.50	120	96.0	7.0	7.0

(ii) High-Altitude Light Duty Vehicles.

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1983-1984	1.20	0.75	30.0	24.0	2.0	2.0
1982	1.20	0.75	45.0	36.0	2.0	2.0

(iii) Light Duty Trucks (0 - 6000 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1996+						
(≤3750 LVW)	0.60	0.40	10.0	8.0	1.5	1.5
(>3750 LVW)	0.80	0.50	13.0	10.0	1.8	1.8
1988-1995	1.60	1.00	40.0	32.0	2.5	2.5
1984-1987	1.60	1.00	40.0	32.0	4.5	4.5
1979-1983	3.40	2.00	70.0	56.0	4.5	4.5
1975-1978	4.00	2.50	80.0	64.0	6.0	6.0
1973-1974	7.00	4.50	120	96.0	6.0	6.0
1968-1972	7.00	4.50	120	96.0	7.0	7.0

(iv) High-Altitude Light Duty Trucks (0 - 6000 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1988+	2.00	1.25	60.0	48.0	2.5	2.5
1984-1987	2.00	1.25	60.0	48.0	4.5	4.5

1982-1983	4.00	2.50	90.0	72.0	4.5	4.5
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(v) Light Duty Trucks (6001 - 8500 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1996+						
(≤5750 ALVW)	0.80	0.50	13.0	10.0	1.8	1.8
(>5750 ALVW)	0.80	0.50	15.0	12.0	2.0	2.0
1988-1995	1.60	1.00	40.0	32.0	3.5	3.5
1984-1987	1.60	1.00	40.0	32.0	4.5	4.5
1979-1983	3.40	2.00	70.0	56.0	4.5	4.5
1975-1978	4.00	2.50	80.0	64.0	6.0	6.0
1973-1974	7.00	4.50	120	96.0	6.0	6.0
1968-1972	7.00	4.50	120	96.0	7.0	7.0

(vi) High-Altitude Light Duty Trucks (6001 - 8500 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1988+	2.00	1.25	60.0	48.0	3.5	3.5
1984-1987	2.00	1.25	60.0	48.0	4.5	4.5
1982-1983	4.00	2.50	90.0	72.0	4.5	4.5

(vii) Heavy-Duty Trucks (greater than 8500 pounds GVWR).

<u>Model Years</u>	<u>Hydrocarbons</u>		<u>Carbon Monoxide</u>		<u>Oxides of Nitrogen</u>	
	Composite	Phase 2	Composite	Phase 2	Composite	Phase 2
1998+	2.00	1.30	30.0	24.0	4.0	4.0
1991-1997	2.00	1.30	40.0	32.0	5.0	5.0
1987-1990	2.00	1.30	40.0	32.0	6.0	6.0
1985-1986	3.00	1.90	50.0	40.0	6.0	6.0
1979-1984	5.00	3.10	75.0	60.0	6.0	6.0
1974-1978	10.0	6.30	150.0	120.0	10.0	10.0
1970-1973	10.0	6.30	175.0	140.0	10.0	10.0
pre-1970	20.0	12.50	200.0	160.0	15.0	15.0

(4) Fast-Pass. Vehicles may be fast-passed using the following algorithm.

- (i) Fast-Pass Algorithm. Beginning at second 30 of the driving cycle, cumulative second-by-second emission levels for each second, calculated from the start of the cycle in grams, shall be compared to the cumulative fast-pass emission standards for the second under consideration. For exhaust components subject to Phase 2 standards, cumulative second-by-second emission levels calculated in grams from second 109 forward shall be compared to cumulative second-by-second fast-pass Phase 2 emission standards for the second under consideration.
- (ii) Fast-Pass Standards. A vehicle shall pass the IM240 for a given exhaust component if either of the following conditions occur:

- (A) cumulative emissions of each exhaust are below the full cycle fast-pass standard for the second under consideration; or,
 - (B) at second 109 and later, (if the exhaust component is subject to Phase 2 standards) cumulative Phase 2 emissions of each exhaust component are below the Phase 2 fast-pass standards for the second under consideration;
- (iii) Fast-Pass End of Test. Testing may be terminated when fast-pass criteria are met for all subject exhaust components.
 - (iv) Applicability of Fast-Pass Standards. If a fast-pass determination cannot be made for all subject exhaust components before the driving cycle ends, the pass/fail determination for each component shall be based on composite or Phase 2 emissions over the full driving cycle as described in §85.2205(a)(1).
 - (v) Fast-Pass Algorithms. Vehicles may be fast-passed using other approaches if they are approved by the Administrator. States are encouraged to develop and use equations to define fast-pass standards for each composite emission standard rather than using tabular standards for each second of the test.

EPA-developed, tabular, fast-passed standards are included in Appendix A.

Fast-pass standards developed by Radian for Colorado are included in Appendix B.

Appendix C contains fast-pass standards generated by EPA for Wisconsin at the state's request. This was done to allow the state to move toward implementing final IM240 standards.

Appendix D contains fast-pass guidelines and 0.8 g/mi HC composite standards along with 0.5 g/mi HC Phase 2 cutpoints developed by Sierra Research under contract 68-C4-0056 Work Assignment 2-04. A complete listing of the modal regression coefficients would be too large to print in an appendix; however, the description in Appendix D is intended to provide background information and the rationale behind this methodology. A complete series of coefficients are available on EPA's web site.

(b) Transient Test Score Calculations

- (1) Composite Scores. The composite scores for the test shall be determined by dividing the sum of the mass of each exhaust component obtained in each second of the test by the number of miles driven in the test. The first data point is the sample taken from t=0 to t=1. The composite test value shall be calculated by the equation in §85.2205(b)(1)(i):

$$(i) \quad \text{Composite gpm} = \frac{\sum_{s=0}^s \text{emissions(g)}}{\sum_{s=0}^s \text{distance(miles)}}$$

Where: s = duration of test in seconds for fast pass
= 239 seconds for complete IM240

(2) Second-by-Second Mass Calculations. The mass of each exhaust component shall be calculated to five significant digits for each second of the test using the following equations:

$$(i) \quad \text{Hydrocarbon mass: HC}_{\text{mass}} = V_{\text{mix}} * \text{Density}_{\text{HC}} * \frac{\text{HC}_{\text{conc}}}{1,000,000}$$

$$(ii) \quad \text{Carbon Monoxide mass: CO}_{\text{mass}} = V_{\text{mix}} * \text{Density}_{\text{CO}} * \frac{\text{CO}_{\text{conc}}}{1,000,000}$$

$$(iii) \quad \text{Oxides of Nitrogen mass: NO}_{\text{xmass}} = V_{\text{mix}} * \text{Density}_{\text{NO}_2} * K_{\text{H}} * \frac{\text{NO}_{\text{conc}}}{1,000,000}$$

$$(iv) \quad \text{Carbon Dioxide mass: CO}_{2\text{mass}} = V_{\text{mix}} * \text{Density}_{\text{CO}_2} * \frac{\text{CO}_{2\text{conc}}}{100}$$

(3) Meaning of Terms.

(i) V_{mix} = The CVS flow rate in cubic feet per second corrected to standard temperature and pressure.

- (ii) HC_{mass} = Hydrocarbon emissions in grams per second.
- (iii) $Density_{HC}$ = Density of hydrocarbons is 16.33 grams per cubic foot assuming an average carbon to hydrogen ratio of 1:1.85 at 68°F and 760 mm Hg pressure.
- (iv) HC_{conc} = Average hydrocarbon concentration per second of the dilute exhaust sample corrected for background, in ppm carbon equivalent, i.e., equivalent propane * 3.

(A) $HC_{conc} = HC_e - HC_d \left(1 - \frac{1}{DF}\right)$ Where:

(B) HC_e = Hydrocarbon concentration of the dilute exhaust sample, in ppm carbon equivalent.

(C) HC_d = Background hydrocarbon concentration of the dilution air, in ppm carbon equivalent.

(D) $DF = \frac{13.4}{CO_{2e} + (HC_e + CO_e) * 10^{-4}}$

This is calculated on a second-by-second basis, where CO_2 is measured in % and HC and CO are measured in ppm. Note this DF does not account for pollutants in the background air and becomes less accurate as the air-fuel ratio of the vehicle deviates from stoichiometric.

(E) $DF_{alt} = \frac{100 - K_1(CO_{2d}) - K_2(CO_d) - K_3(HC_d)}{K_1(CO_{2e} - CO_{2d}) + K_2(CO_e - CO_d) + K_3(HC_e - HC_d)}$

This method of calculating DF is also done on a second-by-second basis and accounts for pollutants in the background air as well as being more accurate than the method in (D) above when the vehicle deviates from stoichiometric operation. All concentrations are expressed in volume percent and the values of the constants for gasoline fuel are: $K_1=6.5431$, $K_2=4.6561$, and $K_3=57.0945$. Appendix E contains additional information on this subject.

If raw emission scores are being determined from dilute measurements, EPA recommends the use of this method for calculating DF.

- (v) CO_{mass} = Carbon monoxide emissions in grams per second.
- (vi) $Density_{CO}$ = Density of carbon monoxide is 32.97 grams per cubic foot at 68°F and 760 mm Hg pressure.

(vii) CO_{conc} = Average carbon monoxide concentration per second of the dilute exhaust sample, corrected for background, water vapor, and CO_2 extraction, in ppm.

$$(A) \quad CO_{conc} = CO_e - CO_d \left(1 - \frac{1}{DF}\right)$$

(B) CO_e = Carbon monoxide concentration of the dilute exhaust, in ppm.

(C) CO_d = Background carbon monoxide concentration of the dilution air, in ppm.

(viii) NO_{xmass} = Oxides of nitrogen emissions in grams per second.

(ix) $Density_{NO_2}$ = Density of oxides of nitrogen is 54.16 grams per cubic foot assuming they are in the form of nitrogen dioxide at 68°F and 760 mm Hg pressure.

(x) NO_{xconc} = Average concentration of oxides of nitrogen per second of the dilute exhaust sample, corrected for background in ppm.

$$(A) \quad NO_{xconc} = NO_{xe} - NO_{xd} \left(1 - \frac{1}{DF}\right)$$

(B) NO_{xe} = Oxides of nitrogen concentration of the dilute exhaust sample, in ppm.

(C) NO_{xd} = Background oxides of nitrogen concentration of the dilution air, in ppm.

(xi) K_H = humidity correction factor

(A) Standard Method

$$K_H = \frac{1.0}{1.0 - 0.0047 * (H - 75.0)}$$

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

$$= \frac{43.478 * R_a * P_d}{P_b - \left(P_d * \frac{R_a}{100}\right)}$$

(C) R_a = Relative humidity of the ambient air, percent.

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

(E) P_b = Barometric pressure, mm Hg.

(F) Revised method²

$$K_H = e^{[0.004977(H-75) - 0.0004447(T-75)]}$$

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

(H) T = Temperature in °F.

NOTE: If the calculated K_H using either method of calculation is greater than 2.19, the value of K_H shall be set at 2.19.

(xiii) CO_{2mass} = Carbon dioxide emissions in grams per second.

(xiv) $Density_{CO_2}$ = Density of carbon dioxide is 51.81 grams per cubic foot at 68°F and 760 mm Hg.

(xv) CO_{2conc} = Average carbon dioxide concentration per second of the dilute exhaust sample, corrected for background, in percent.

$$(A) \quad CO_{2conc} = CO_{2e} - CO_{2d} \left(1 - \frac{1}{DF}\right)$$

(B) CO_{2d} = Background carbon dioxide concentration of the dilution air, in percent.

(4) Negative Values. Negative gram per second readings shall be integrated as zero and recorded as such. Negative values measured for ambient background concentrations (HC_d , CO_d , CO_{2d} , and NO_{xd}) used in 85.2205(b)(3) shall be calculated as zero and recorded as such.

(5) Determination of Raw Exhaust Concentrations from IM240 Results. Although the IM240 is a mass-based test, it is possible to estimate tailpipe concentrations from the dilute measurements for those vehicles only required to undergo an idle test. One method for performing this

²This revised method for calculating K_H as a function of both T and H is based on work performed by Sierra Research under contract 68-C4-0056, Work Assignment 2-04. If the calculated value of K_H exceeds 2.19, the value of K_H shall be set to 2.19. This analysis used the same MY69, 5-vehicle sample employed for the original K_H factor study that resulted in the current CFR standard K_H calculation method (listed in (xi)(A) above). However, in many cases IM testing occurs outside the temperature limits set by the CFR for the standard method; therefore, at this time EPA recommends using the revised method when testing above 86°F.

calculation can be found in SAE manuscript 980678. Additional clarification on this can be found in Appendix E.

(c) Evaporative System Purge Test Standards

The current purge test described below has proven to be problematic for high-volume I/M lane testing. In recognition of its limitations in centralized I/M test programs, EPA is not currently encouraging states to initiate such testing. It is included here as some de-centralized test programs may be able to successfully use such a test.

The methods described below are applicable to pre OBD II evaporative emission controlled vehicles. OBD II vehicles equipped with evaporative control monitors and certified to the enhanced evaporative emission standards are being phased-in beginning with the 1996 model year. Those vehicles must be tested using OBD II scan tools or by measuring equivalent purge flow through an evaporative emission "service port." Procedures for OBD evaporative emission controlled vehicles will be added at a later date.

- (1) Visual Check. The vehicle shall fail the evaporative system visual check if any part of the system is missing, damaged, improperly connected, or disconnected as described in §85.2222(b).
- (2) Total Flow Method. The vehicle shall pass the purge test when the total volume of flow exceeds 1.0 standard liters. If total volume of flow is less than 1.0 standard liter at the conclusion of the transient driving cycle, the vehicle shall fail. Any measurement below the noise specification in §85.2227(b)(2)(vi) shall not be included in the total flow calculation.
- (3) Qualitative Flow Methods. A pass or fail determination of a vehicle purge system may also be made by qualitative methods. Such designs need not report numerical values, and would simply report the test result as passing (flow was detected) or failing (no flow was detected).

(d) Evaporative System Pressure Test Standards

The methods described below are applicable to pre OBD II evaporative emission controlled vehicles. OBD II vehicles equipped with evaporative control monitors and certified to the enhanced evaporative emission standards are being phased-in beginning with the 1996 model year. Those vehicles must be tested using either OBD II scan tools, by measuring pressure loss through an evaporative emission "service port," or by following vehicle manufacturer specific instruction to avoid damaging rigid vapor lines which are prevalent on many vehicles equipped with enhanced evaporative emission control systems. Procedures for OBD evaporative emission controlled vehicles will be added to the guidance at a later date.

All I/M programs conducting a pressure test must perform a leak check on the gas cap and provide a unique test result.

- (1) Visual Check. The vehicle shall fail the evaporative system visual check if any part of the system is missing, damaged, improperly connected, or disconnected as described in §85.2222(b).

(2) Fuel Inlet Pressure Test.

- (i) Pressure Test Method. A vehicle shall fail the pressure test if the fuel vapor control system isolated between the fuel inlet and a clamp on the line between the fuel tank and the canister, (located as close to the canister as possible) loses more than 8 inches of water pressure over a period of 120 seconds starting from a stabilized pressure of 14±1 inch of water.
- (ii) Fast-Pass. Fast-pass determinations for the pressure test may be made anytime during the pressure decay between 20 and 120 seconds if the measured pressure exceeds:

$$P_m = P_i - \left(\frac{0.33 * P_i + 1.33}{120} \right) * t$$

Where: P_m = Measured pressure in inches of water

P_i = Initial pressure in inches of water

t = Time in seconds

(e) **Gas Cap Test Standards**

The methods described below are applicable to pre OBD II evaporative emission controlled vehicles. OBD II vehicles equipped with evaporative control monitors and certified to the enhanced evaporative emission standards are being phased-in beginning with the 1996 model year. Procedures for OBD evaporative emission controlled vehicles will be added at a later date.

Pressure decay methods using a 1 liter head space are currently permitted under the June 1996 version of the IM240 technical guidance. As this method has been widely used in IM240 testing it will continue to be allowed. The pressure decay loss of 6 inches of WC from a starting pressure of 28 in. WC referenced to 70F and 1 atm and assuming a 1 liter head space, equates to a flow rate of about 80 cc/min.

- (1) Visual Check. The vehicle shall fail the gas cap visual check if the cap is missing, obviously defective, or the wrong style cap for the vehicle. An example of a wrong style includes a cam lock cap installed on fill pipe which requires a threaded cap. States conducting cap testing should work with OEM suppliers to develop a user friendly method of identifying wrong style gas caps.
- (2) Pressure Decay Test Standard. For pressure decay methods using a 1 liter head space and the June 1996 IM240 technical guidance, the fuel cap shall fail the pressure test if it loses more than 6 inches of water column (WC) pressure over a period of 10 seconds from a starting pressure of 28±1 inch WC.
- (3) 60 cc/min Flow Standard. The gas cap leak rate may be determined by pressure loss measurement, direct flow measurement, or flow comparison methods and shall be compared to a pass/fail flow rate standard of 60 cubic centimeters per minute of air at 30 inches of water column. The flow rate methods shall be referenced to standard conditions of 70 °F and 1 atm.

If the leak rate exceeds 60 cc/min at a pressure of 30 inches of water column, the cap shall fail the test.

(a) General Requirements

- (1) Test Parameters. The following information shall be determined for the vehicle being tested and used to automatically select the dynamometer inertia, power absorption settings, and evaporative emission test parameters.

- (i) Model Year
- (ii) Manufacturer
- (iii) Model name
- (iv) Body style
- (v) Number of cylinders
- (vi) Engine displacement

Alternative computerized methods of selecting dynamometer test conditions, such as VIN decoding, may be used.

- (2) Ambient Conditions. The ambient temperature, absolute humidity, and barometric pressure shall be recorded continuously during the transient test, or as a single set of readings if taken less than 4 minutes prior to the transient driving cycle.
- (3) Restart. If shut off, the vehicle shall be restarted as soon as possible before the test and shall be running at least 30 seconds prior to the transient driving cycle.

(b) Pre-inspection and Preparation

- (1) Accessories. All accessories (air conditioning, heat, defogger, radio, automatic traction control if switchable, etc.) shall be turned off by the inspector, if necessary.
- (2) Traction Control and Four-Wheel Drive (4WD). Vehicles with traction control systems that cannot be turned off shall not be tested on two wheel drive dynamometers. Vehicles with 4WD that cannot be turned off shall only be tested on 4WD dynamometers. If the 4WD function can be disabled, then 4WD vehicles may be tested on two wheel drive dynamometers.
- (3) Leaks. The vehicle shall be inspected for exhaust leaks. Audio assessment while blocking exhaust flow, or measurement of carbon dioxide or other gases, shall be acceptable. Vehicles with leaking exhaust systems shall be rejected from testing.
- (4) Operating Temperature. The vehicle temperature gauge, if equipped and operating, shall be checked to assess temperature. If the temperature gauge indicates that the engine is well below (less than 180°F) normal operating temperature, the vehicle shall not be fast-failed and shall get a second-chance emission test if it fails the initial test for any criteria exhaust component. Vehicles in overheated condition shall be rejected from testing.
- (5) Tire Condition. Vehicles shall be rejected from testing if tire cords, bubbles, cuts, or other damage are visible. Vehicles shall be rejected that have space-saver spare tires on the drive axle. Vehicles may be rejected if they do not have reasonably sized tires. Vehicle tires shall be visually checked for adequate pressure level. Drive wheel tires that appear low shall be inflated

to approximately 30 psi, or to tire side wall pressure, or manufacturer's recommendation. The tires of vehicles being tested for the purposes of program evaluation under §51.353(c) shall have their tires inflated to tire side wall pressure.

- (6) Ambient Background. Background concentrations of hydrocarbons, carbon monoxide, oxides of nitrogen, and carbon dioxide (HC, CO, NO_x, and CO₂, respectively) shall be sampled as specified in §85.2226(b)(2)(iv) to determine background concentration of dilution air. The sample shall be taken for a minimum of 15 seconds within 120 seconds of the start of the transient driving cycle, using the same analyzers used to measure tailpipe emissions except as provided in §85.2226(c)(4)(iv). Average readings over the 15 seconds for each gas shall be recorded in the test record. Testing shall be prevented until the average ambient background levels are less than 20 ppmC HC, 30 ppm CO, and 2 ppm NO_x, or outside ambient air levels (not influenced by station exhaust), whichever are greater.

Other methods that do not employ a fixed analysis time of 15 seconds may be used, if approved by the Administrator.

- (7) Sample System Purge. While a lane is in operation, the CVS shall continuously purge the CVS hose between tests. The blower may be turned off if the CVS is not in operation, but the system shall be purged for 2 minutes prior to the start of a test if the blower has been turned off. The off time shall be computer monitored and recorded to a history file for quality assurance.

(c) Equipment Positioning and Settings

- (1) Purge Equipment. If an evaporative system flow meter purge test is to be performed:
 - (i) The purge flow meter shall be connected in series between the evaporative canister and the engine.
 - (ii) All hoses disconnected for the test shall be reconnected after a purge flow test is performed.
- (2) Roll Rotation. The vehicle shall be maneuvered onto the dynamometer with the drive wheels positioned on the dynamometer rolls. Prior to test initiation, the rolls shall be rotated until the vehicle laterally stabilizes on the dynamometer. Drive wheel tires shall be dried if necessary to prevent slippage during the initial acceleration.
- (3) Cooling System. The use of a cooling system is optional when testing at temperatures below 50°F. Furthermore, the hood may be opened at the state's discretion. If a cooling system is in use, testing shall not begin until the cooling system is positioned and activated. The cooling system shall be positioned to direct air to the vehicle cooling system, but shall not be directed at the catalytic converter.
- (4) Vehicle Restraint. Testing shall not begin until the vehicle is restrained. Any restraint system shall meet the requirements of §85.2226(a)(5)(vii). The parking brake shall be set for front wheel drive vehicles prior to the start of the test. The parking brake need not be set for vehicles that release the parking brake automatically when the transmission is put in gear.

- (5) Dynamometer Settings. Dynamometer power absorption and inertia weight settings shall be automatically chosen from an EPA-supplied electronic look-up table which will be referenced based upon the vehicle identification information obtained in 85.2221(a)(1). Vehicles not listed shall be tested using default power absorption and inertia settings in the latest version of the EPA I/M Look-up Table, as posted on EPA's web site: www.epa.gov/orcdizux/im.htm
- (6) Exhaust Collection System. The exhaust collection system shall be positioned to insure complete capture of the entire exhaust stream from the tailpipe during the transient driving cycle. The system shall meet the requirements of §85.2226(b)(2).

(d) Vehicle Conditioning

- (1) Queuing Time. When the vehicle queue exceeds 20 minutes, a vehicle shall get a second-chance emission test if it fails the initial test and all criteria exhaust components are at or below 1.5 times the standard. At the state's discretion, second-chance testing may be granted if criteria exhaust components exceed any preset level above the standard.
- (2) Program Evaluation. Vehicles being tested for the purpose of program evaluation under §51.353(c) shall receive two full transient emission tests (i.e., a full 240 seconds each). Results from both tests and the test order shall be separately recorded in the test record. Emission scores and results provided to the motorist may be from either test.
- (3) Discretionary Preconditioning.
 - (i) Any vehicle may be preconditioned by maneuvering the vehicle on to the dynamometer and driving the 94 to 239 second segment of the transient cycle in 85.2221(e)(1). This method has been demonstrated to adequately precondition the vast majority of vehicles (SAE 962091).

Other preconditioning cycles may be developed and used if approved by the Administrator.
 - (ii) Alternatively, modal analysis of the failing second-by-second test data may be performed to identify vehicles that would benefit from additional pre-conditioning. Appendix F provides retest criteria developed by Sierra Research under EPA contract 68-C4-0056 Work Assignment 2-04.
- (4) Second-Chance Purge Testing. If purge testing is performed, vehicles that fail the purge test may receive a second-chance purge test. The second-chance test may be the Transient Driving Cycle or modified sequences of shorter duration designed to rapidly produce purge activity.

(e) **Vehicle Emission Test Sequence**

(1) Transient Driving Cycle. The vehicle shall be driven over the following cycle:

Time second	Speed mph	Time second	Speed mph	Time second	Speed mph	Time second	Speed mph	Time second	Speed mph
0	0	48	25.7	96	0	144	24.6	192	54.6
1	0	49	26.1	97	0	145	24.6	193	54.8
2	0	50	26.7	98	3.3	146	25.1	194	55.1
3	0	51	27.5	99	6.6	147	25.6	195	55.5
4	0	52	28.6	100	9.9	148	25.7	196	55.7
5	3	53	29.3	101	13.2	149	25.4	197	56.1
6	5.9	54	29.8	102	16.5	150	24.9	198	56.3
7	8.6	55	30.1	103	19.8	151	25	199	56.6
8	11.5	56	30.4	104	22.2	152	25.4	200	56.7
9	14.3	57	30.7	105	24.3	153	26	201	56.7
10	16.9	58	30.7	106	25.8	154	26	202	56.3
11	17.3	59	30.5	107	26.4	155	25.7	203	56
12	18.1	60	30.4	108	25.7	156	26.1	204	55
13	20.7	61	30.3	109	25.1	157	26.7	205	53.4
14	21.7	62	30.4	110	24.7	158	27.3	206	51.6
15	22.4	63	30.8	111	25.2	159	30.5	207	51.8
16	22.5	64	30.4	112	25.4	160	33.5	208	52.1
17	22.1	65	29.9	113	27.2	161	36.2	209	52.5
18	21.5	66	29.5	114	26.5	162	37.3	210	53
19	20.9	67	29.8	115	24	163	39.3	211	53.5
20	20.4	68	30.3	116	22.7	164	40.5	212	54
21	19.8	69	30.7	117	19.4	165	42.1	213	54.9
22	17	70	30.9	118	17.7	166	43.5	214	55.4
23	14.9	71	31	119	17.2	167	45.1	215	55.6
24	14.9	72	30.9	120	18.1	168	46	216	56
25	15.2	73	30.4	121	18.6	169	46.8	217	56
26	15.5	74	29.8	122	20	170	47.5	218	55.8
27	16	75	29.9	123	20.7	171	47.5	219	55.2
28	17.1	76	30.2	124	21.7	172	47.3	220	54.5
29	19.1	77	30.7	125	22.4	173	47.2	221	53.6
30	21.1	78	31.2	126	22.5	174	47.2	222	52.5
31	22.7	79	31.8	127	22.1	175	47.4	223	51.5
32	22.9	80	32.2	128	21.5	176	47.9	224	50.5
33	22.7	81	32.4	129	20.9	177	48.5	225	48
34	22.6	82	32.2	130	20.4	178	49.1	226	44.5
35	21.3	83	31.7	131	19.8	179	49.5	227	41
36	19	84	28.6	132	17	180	50	228	37.5
37	17.1	85	25.1	133	17.1	181	50.6	229	34
38	15.8	86	21.6	134	15.8	182	51	230	30.5
39	15.8	87	18.1	135	15.8	183	51.5	231	27
40	17.7	88	14.6	136	17.7	184	52.2	232	23.5
41	19.8	89	11.1	137	19.8	185	53.2	233	20
42	21.6	90	7.6	138	21.6	186	54.1	234	16.5

43	23.2	91	4.1	139	22.2	187	54.6	235	13
44	24.2	92	0.6	140	24.5	188	54.9	236	9.5
45	24.6	93	0	141	24.7	189	55	237	6
46	24.9	94	0	142	24.8	190	54.9	238	2.5
47	25	95	0	143	24.7	191	54.6	239	0

- (2) **Driving Trace.** The inspector shall follow an electronic, visual depiction of the time/speed relationship of the transient driving cycle, or trace. The visual depiction of the trace shall be of sufficient magnification and adequate detail to allow accurate tracking by the driver and shall permit the driver to anticipate upcoming speed changes. The trace shall also clearly indicate gear shifts as specified in §85.2221(e)(3).
- (3) **Shift Schedule.** For vehicles with manual transmissions, inspectors shall shift gears according to the following shift schedule:

Shift Sequence (<i>gear</i>)	Speed (<i>miles per hour</i>)	Nominal Cycle Time (<i>seconds</i>)
1 - 2	15	9.3
2 - 3	25	47.0
De-clutch	15	87.9
1 - 2	15	101.6
2 - 3	25	105.5
3 - 2	17	119.0
2 - 3	25	145.8
3 - 4	40	163.6
4 - 5	45	167.0
5 - 6	50	180.0
De-clutch	15	234.5

Gear shifts shall occur at the points in the driving cycle where the specified speeds are obtained. For vehicles with fewer than six forward gears the same schedule shall be followed while disregarding shifts above the highest gear.

- (4) **Speed Excursion Limits.** Speed excursion limits shall apply as follows:
- (i) **Upper Limit.** The upper limit is 2 mph higher than the highest point on the trace within 1 second of the given time.
 - (ii) **Lower Limit.** The lower limit is 2 mph lower than the lowest point on the trace within 1 second of the given time.
 - (iii) **Speed Variations.** Speed variations greater than the tolerances (such as may occur during gear changes) are acceptable provided they occur for no more than 2 seconds on any occasion.
 - (iv) **Underpowered Vehicles.** Speeds lower than those prescribed during accelerations are acceptable provided the vehicle is operated at maximum available power during such accelerations until the vehicle speed is within the excursion limits. If the vehicle is underpowered and unable to adequately follow the trace, it may at the State's discretion be rejected from testing or given an idle test.

- (v) Exceedances. Exceedances of the limits in §85.2221(5)(ii) through §85.2221(5)(iii) shall automatically result in a void test. The station manager can override the automatic void of a test if the manager determines that the conditions specified in §85.2221(e)(4)(iv) occurred.

(5) Speed Variation Limits.

- (i) Limits. Based on work performed under contract 68-C4-0056, Work Assignment 2-04 the following Positive Kinetic Energy limits were developed by Sierra Research. These results are based on an analysis of 16,581 IM240 tests conducted in AZ.

$$(ii) \quad PKE = \frac{\sum_{t=0}^t PP_t}{\int_{x=0}^x dx}$$

where: $PP_t = V_t^2 - V_{(t-1)}^2$ mi²/hr² for $V_t > V_{(t-1)}$

$PP_t = 0$ for $V_t = V_{(t-1)}$

$x =$ distance (mi)

- (iii) PKE Limits. Full Test PKE Limits:

Upper Limit 3456 mi/hr²

Lower Limit 3082 mi/hr²

NOTE: The test cycle shall be invalid for a pass/fail determination if the PKE value is below the lower limit for a passing vehicle or above the upper limit for a failing vehicle. PKE values alone should not be used to make an early pass/fail determination.

Test cycles with PKE values outside the lower and upper limits shall be valid for preconditioning provided that all other requirements are met.

- (iv) Second-by-Second Limits. Second-by-Second PKE upper and lower limits are listed in Appendix G.

- (6) Distance Criteria. The actual distance traveled for the transient driving shall be measured. If the absolute difference between the measured distance and the theoretical distance for the actual test exceeds 0.05 miles, the test shall be void.

- (7) Vehicle Stalls. Vehicle stalls during the test shall void the test and result in a new test. More than 3 stalls shall result in rejecting the vehicle from testing.

- (8) Inertia Weight Selection. The inertia weight selected for the vehicle shall be verified as specified in §85.2226(a)(1)(i). For systems employing electrical inertia simulation, an algorithm identifying the actual inertia force applied during the transient driving cycle shall be used to determine proper inertia simulation.
- (9) CVS Operation. The CVS operation shall be verified for each test for a CFV-type CVS by measuring either the absolute pressure difference across the venturi or measuring the blower vacuum behind the venturi for minimum levels needed to maintain choke flow for the venturi design. The operation of an SSV-type CVS shall be verified throughout the test by monitoring the difference in pressure between upstream and throat pressure. The minimum values shall be determined from system calibrations. Monitored pressure differences below the minimum values shall void the test.

(f) Emission and Purge Flow Measurements

- (1) Exhaust Measurement. The emission analysis system shall sample and record dilute exhaust HC, CO, CO₂, and NO_x during the transient driving cycle as described in §85.2226(c).
- (2) Purge Measurement. The analysis system shall measure purge flow in standard liters per second and record total volume of flow in standard liters over the course of the actual driving cycle as described in §85.2227(b). Qualitative methods that demonstrate the presence of purge flow between the canister and the engine intake are an acceptable alternative to quantitative methods.

(a) General Requirements

- (1) Pressure Test. The on-vehicle pressure tests described in §85.2222(c) shall be performed after any tailpipe emission test. Vehicles receiving a pressure test specified in §85.2222(c) should also be given a gas cap leak test specified in §85.2222(d).
- (2) Controlling Test Variability. The pressure test shall be conducted in a manner that minimizes changes in temperature, since pressure measurements are affected by changes in the vapor space temperature. Volume compensation for the pressure test is not required, but the vapor space volume will affect the pressure decay measurement.
- (3) Gas Cap Test Requirement. A gas cap test described in §85.2222(d) may be performed before or after the tailpipe emission test.
- (4) Alternative Techniques. Alternative gas cap or pressure test procedures may be used if they are shown to be equivalent or better than those described below.

(b) Pre-inspection and Preparation

- (1) Visual Inspection - Canister. The evaporative canister(s) shall be visually checked to the degree practical. A missing or obviously damaged canister(s) shall fail the visual evaporative system check.
- (2) Visual Inspection - System. The evaporative system hoses shall be visually inspected for the appearance of proper routing, connection, and condition, to the degree practical. If any evaporative system hose is misrouted, disconnected, or damaged, the vehicle shall fail the visual evaporative system check.
- (3) Visual Inspection - Gas Cap. If the gas cap is missing, obviously defective, or the wrong style cap for the vehicle, the vehicle shall fail the visual inspection.

(c) Fuel Inlet Pressure Test

- (1) Equipment Set-up. The vapor vent line(s) from the gas tank to the canister(s) shall be clamped off as close to the canister(s) as practical without damaging evaporative system hardware. Dual fuel tanks shall be checked individually if the complete vapor control system can not be accessed by pressurizing from the fill pipe interface of only one fuel tank. The proper adapter, as specified in §85.2227(c)(2)(i) shall be selected.
- (2) Starting Pressure. The gas tank shall be pressurized to 14 ± 1 inch of WC, or a vehicle specific pressure as identified in the I/M Look-up Table.
- (3) Stability. Pressure stability shall be monitored for a period of 10 seconds prior to the start of the pressure decay measurement. One definition of stability is a loss of no more than 5 inches WC over a 10 second period when the initial pressure is 14 ± 1 inch WC. If the loss of pressure in 10 seconds exceeds this value, two more attempts shall be made to reach stability. Failure to achieve stability likely indicates the presence of a large leak and therefore failure of the pressure test. Alternate definitions of stability may be proposed by the State and approved by the Administrator. Stability criteria for flow comparator or direct flow measurement methods do not apply.
- (4) Volume Compensation. Pressure decay measurements are affected by the vapor volume in the fuel tank. Volume-compensated pressure decay measurements are presently not required. By

design, flow comparator or flow measurement methods do not require volume corrections.

- (5) Pressure Monitoring. Close the pressure source and measure the loss in pressure over a 120 second interval. Fast-pass determinations may be made using the equations in §85.2205(d)(2)(ii).
- (6) Clamp Removal. Remove the clamp on the vapor line and carefully relieve pressure and remove the adapter used to supply pressure to the vapor space.

(d) Gas Cap Test

- (1) Cap Installation. The fuel cap, or caps, shall be removed from the fuel inlet(s) and installed on a portable or bench test rig -using the adapter appropriate for the gas cap as specified in §85.2227(d)(1)(ii).
- (2) Leak Measurement. The gas cap leak rate shall be measured and compared against a 60 cc/min at 30 in. WC flow standard. Pressure decay measurement using instruments with a 1 liter head space shall be made from an initial pressure of 28 in. WC and be compared against a loss of 6 in. WC in 10 seconds.
- (3) Cap Replacement. The fuel cap(s) shall be replaced on the fuel inlet and tightened appropriately.

(a) **Dynamometer Specifications**(1) General Requirements.

- (i) Capacity. The dynamometer structure (e.g., bearings, rollers, pit plates, etc.) shall accommodate all light-duty vehicles and light-duty trucks up to 8500 pounds GVWR.
- (ii) Test Parameters. Road load horsepower and inertia simulation shall be automatically selected from the EPA I/M Look-up Table, or equivalent data base, based on the vehicle parameters in the test record.
- (iii) Alternative Designs. Alternative dynamometer specifications, designs, and quality monitors may be used if the alternative provides accurate dynamometer loading over the IM240 driving cycle.
- (iv) Units. Specifications in this section are generally expressed in units of horsepower. System designs using equivalent units of force, English or SI, are permissible.
- (v) Ambient Range. The dynamometer shall be designed to meet specifications at an ambient temperature range of 35 to 110°F, and at absolute humidity values representative of the IM240 testing location.

(2) Power Absorption.

- (i) Power Absorber Design. The power absorber unit shall be an electric AC or DC motor/absorber design. Eddy current designs may be approved if proven equivalent to other designs in terms of inertia response time, total load, and emissions performance over an IM240 driving cycle.
- (ii) Range.
 - (A) Mechanical Inertia Dynamometers. Dynamometers using clutchable flywheels shall have sufficient power absorber capacity to accommodate the TRLHP values in the EPA I/M Look-up Table.
 - (B) Electric Inertia Dynamometers. Dynamometers using a combination of mechanical base inertia and supplemental electrical inertia shall have sufficient power absorber capacity to accommodate the sum of the TRLHP values in the EPA I/M Look-up Table plus the power absorbed from accelerating a vehicle at 3.3 mph/sec at the equivalent test weight (ETW) specified in the I/M Look-up Table.
- (iii) Accuracy. The power absorber shall be adjustable across the required horsepower range at 50 mph in 0.1 horsepower increments. The accuracy of the power absorber or power exchange unit, for road load simulation only, shall be ± 0.25 horsepower or $\pm 3\%$ of point, whichever is greater.
- (iv) Indicated Horsepower. At constant velocity, the power absorber shall load the vehicle according the following equations:

$$\text{IHP} = \text{TRLHP} - \text{PLHP} - \text{GTRL}$$

Where: IHP is the dynamometer indicated, or set, horsepower.

TRLHP is the track, or total, horsepower for a particular vehicle.

PLHP is the dynamometer parasitic loss horsepower.

GTRL is the generic tire/roll loss of a vehicle on the dynamometer.

TRLHP, PLHP, GTRL, and therefore IHP, are all expressed as three term polynomials of the type:

$$HP = A * Obmph + B * Obmph^2 + C * Obmph^3$$

Where: HP represents individual expressions relating IHP, TRLHP, PLHP, or GTRL as a function of velocity.

A, B, or C represent horsepower coefficients for the individual expressions relating IHP, TRLHP, PLHP, or GTRL as a function of velocity.

Obmph is the velocity in miles per hour.

Expressions for TRLHP, and GTRL are found in Appendices H and I.

(3) Inertia.

- (i) Range. The dynamometer shall provide inertia simulation capability of 2000 to 5500 pounds for light duty vehicles and trucks less than or equal to 5500 pounds ETW. Dynamometers used for testing light duty vehicles and trucks over 5500 ETW shall have inertia simulation capability to set the inertia at the correct value as referenced in the EPA I/M Look-up Table.
- (ii) Mechanical Inertia Simulation. The dynamometer shall be equipped with clutchable mechanical flywheels with inertia selectable to a 250 pound sensitivity. The tolerance on the base inertia weight and the flywheels shall be within 1% of the specified test weights. The test system shall be equipped with a method, independent from the flywheel selection system, that identifies which flywheels are actually rotating during the transient driving cycle.
- (iii) Electric Inertia Simulation. Electric inertia simulation, or a combination of electric and mechanical simulation may be used in lieu of mechanical flywheels, provided that the performance of the electrically simulated inertia complies with the following specifications.
 - (A) System Response. The torque response to a step change shall be at least 90% of the command value within 200 milliseconds, and shall be within 2 percent of the commanded torque by 300 milliseconds after the command is issued. Any overshoot of the commanded torque value shall not exceed 25 percent of the torque value. Response time measurements shall be performed at 2500, 4000, and 5500 pounds of inertia.
 - (B) Simulation Error. An inertia simulation error (ISE) shall be continuously calculated any time the actual dynamometer speed is between 10 and 60 mph. The average positive ISE over the driving cycle shall be calculated by the equation in §85.2226(a)(3)(iii)(C), and shall not exceed 2 percent of the inertia weight selected (IW_s) for the vehicle under test.

$$(C) \quad ISE = \frac{(IW_s - I_t)}{IW_s} * 100$$

Where: ISE = Inertia simulation error expressed in percent.

IW_s = Total inertia desired, or selected, in pounds mass.

I_t = Total inertia being simulated by the dynamometer in pounds mass.

$$(D) \quad I_t = I_m + \frac{32.2}{V} \int_{t=0}^t (F_m - F_{rl}) dt$$

Where: I_t = Total inertia being simulated by the dynamometer in pounds mass.

I_m = Base mechanical inertia of the dynamometer in pounds mass.

32.2 = Gravitational constant, (ft)(lbm)/(lbf)(sec²).

V = Measured roll speed in feet/second.

F_m = Force measured by the load cell converted to force at the roll surface in pounds.

F_{rl} = Dynamometer road load expressed as a three term polynomial in pounds force at the measured roll speed.

t = Time in seconds.

(4) Dynamometer Parasitic Loss

(i) Friction Curves. The dynamometer internal friction curves, typically bearing and windage friction expressed as a function of velocity, shall be capable of being automatically measured, stored, and accurately accounted for over the IM240 driving cycle.

(ii) Friction Curve Definition. Parasitic loss friction shall be expressed in a tabular format as a function of velocity, or as a polynomial of the type:

$$PLHP = A_p * Obmph + B_p Obmph^2 + C_p Obmph^3$$

Where: PLHP represents the dynamometer parasitic friction, expressed in horsepower.

A_p , B_p , and C_p are coefficients relating a least squares fit of dynamometer friction and velocity.

Obmph is dynamometer roll surface velocity in miles per hour.

(5) Rolls.

- (i) Size and Type. The dynamometer shall be equipped with twin rolls. The rolls shall be coupled side to side. In addition, the front and rear rolls shall be coupled. The dynamometer roll diameter shall be between 8.5 and 21.0 inches. The spacing between the roll centers shall comply with the equation in §85.2226(a)(5)(iii). The dynamometer rolls shall accommodate an inside track width of 30 inches and an outside track width of at least 100 inches.
- (ii) Roll Installation. Rolls shall be installed in the floor such that vehicles will be within ± 5 degrees of horizontal.
- (iii) Roll Spacing. The spacing between the roll centers shall comply with the following equation to within +0.5 inches and -0.25 inches.

$$\text{Roll Spacing} = (24.375 + D) * \text{Sin } 31.5^\circ$$

Where: Roll Spacing is the distance between the roll centerlines in inches.

D = Roll diameter in inches

- (iv) Roll Surface. The surface finish and hardness shall be such that tire slippage is minimized when testing vehicles using the inertia weight and horsepower settings found in the EPA I/M Look-up Table while following the IM240 driving schedule, and that tire wear and noise are minimized. Knurled roll surfaces are acceptable.
- (v) Test Distance and Vehicle Speed. The total number of dynamometer roll revolutions shall be used to calculate the distance traveled. Pulse counters may be used to calculate the distance directly if there are at least 16 pulses per revolution. The measurement of the actual roll distance for the composite and each phase of the transient driving cycle shall be accurate to within ± 0.01 mile. The measurement of the roll speed shall be accurate to within ± 0.1 mph over the IM240 driving schedule.
- (vi) Vehicle Lift. A vehicle lift system located between the dynamometer rolls shall be provided to facilitate drive axle positioning and vehicle egress from the dynamometer.
- (vii) Vehicle Restraint System. The dynamometer shall include a system of safely restraining the forward and side-to-side motion of front wheel drive vehicles, and the forward motion of rear wheel drive vehicles during the IM240 driving schedule, while allowing unobstructed ingress and egress from the dynamometer.

(6) Load Cell.

- (i) Torque Measurement. The dynamometer shall have a torque measurement system accurate to within $\pm 2\%$ of full scale.
- (ii) Dead Weights. Dead weights used to calibrate a torque meter or load cell shall be traceable to NIST and be accurate to within $\pm 0.5\%$.
- (iii) Dynamic Calibrations. Designs using an $F = MA$ method for calibrating the load cell are also acceptable.

(7) Driver's Aid.

- (i) Video Display. The dynamometer shall be equipped with a video display device able to be easily positioned to accommodate all test vehicles while clearly visible to the driver. The display shall have a method that allows the driver to accurately and smoothly follow the desired driving cycle.
 - (ii) Remote Capabilities. The dynamometer shall have a means of allowing the driver to start the test, perform an emergency stop, and perform other necessary and convenient functions related to the test while inside the vehicle.
- (8) Other.
- (i) Augmented Braking. Augmented braking shall be used during vehicle decelerations on the driving cycle. Augmented braking shall be actuated only when the negative force applied by the vehicle at the roll surface is greater than 110 pounds. If the augmented braking is not linked to driver braking, the driver shall be signaled to not accelerate during this period.
 - (ii) Cooling Fan. The cooling fan capacity shall be 5400 ±300 SCFM, positioned within 12 inches of the intake to the vehicle's cooling system, and avoid unrepresentative cooling of the engine and exhaust control system.
- (9) All Wheel Drive Dynamometers.
- (i) Design. The dynamometer shall meet the requirements for two wheel drive vehicles and be capable of testing traction control and all wheel drive vehicles in a safe manner without damaging the vehicle.
 - (ii) Wheelbase. The all wheel drive dynamometer shall be capable of testing vehicles having a wheelbase between 84 and 125 inches, or as necessary to meet the wheelbase values in the I/M Look-up Table. The system shall provide a locking mechanism to secure the roll at the desired wheelbase.
 - (iii) Speed Synchronization. Front and rear wheels shall maintain speed synchronization within ±0.1 mph.
- (b) **Constant Volume Sampler**
- (1) General Design Requirements.
- (i) Venturi Type. A constant volume sampling (CVS) system of the critical flow venturi (CFV) or the sub-sonic venturi (SSV) type shall be used to collect vehicle exhaust samples. The CVS system and components shall generally conform to the specifications in §86.109-90.
 - (ii) CVS Flow Size. The CVS system shall be sized in a manner that prevents condensation in the dilute sample over the range of ambient conditions to be encountered during testing. A 700 SCFM system is assumed to satisfy this requirement. The range of ambient conditions may require the use of heated sample lines. Should heated sample lines be used, the lines and components shall be heated to a minimum of 120°F and a maximum of 250°F, which shall be monitored during the driving cycle.
 - (iii) CVS Compressor. The CVS compressor flow capacity shall be sufficient to maintain proper flow in the main CVS venturi with an adequate margin. For CFV CVSs the

margin shall be sufficient to maintain choke flow. The capacity of the blower relative to the CFV flow capacity shall not be so large as to create a limited surge margin.

- (iv) Materials. All materials in contact with exhaust gas shall be unaffected by and shall not affect the sample (i.e., the materials shall not react with the sample, and neither shall they taint the sample as a result of out gassing). Acceptable materials include stainless steel, Teflon[®], silicon rubber, and Tedlar[®].
- (v) Alternative Designs. Alternative CVS specifications, materials, or designs may be allowed upon a determination by the Administrator, that for the purpose of properly conducting an approved short test, the evidence supporting such deviations will not significantly affect the proper measurement of emissions.

(2) Sample System.

- (i) Sample Probe. The sample probe within the CVS shall be designed such that a continuous and adequate volume of sample is collected for analysis. The system shall have a method for determining if the sample collection system has deteriorated or malfunctioned such that an adequate sample is not being collected, or that the response time has deteriorated such that the time correlation for each emission constituent is no longer valid.
- (ii) CVS Mixing Tee.
 - (A) Design and Effect. The mixing tee for diluting the vehicle exhaust with ambient air shall be at the vehicle tailpipe exit as in §86.109-90(a)(2)(iv). The dilution mixing tee shall be capable of collecting exhaust from all light-duty vehicle and light-duty truck exhaust systems. The design used shall not cause static pressure in the tailpipe to change such that the emission levels are significantly affected. A change of ± 1.0 inch of water or less, as measured at the tailpipe, shall be acceptable.
 - (B) Locating Device. The mixing tee shall have a device for positively locating the tee relative to the tailpipe with respect to distance from the tailpipe, and with respect to positioning the exhaust stream from the tailpipe(s) in the center of the mixing tee flow area. The locating device, or the size of the entrance to the tee shall be such that if a vehicle moves laterally from one extreme position on the dynamometer to the other extreme, that mixing tee will collect all of the exhaust sample.
- (iii) Dual Exhaust. For dual exhaust systems, the design used shall insure that each leg of the sample collection system maintains equal flow. Equal flow will be assumed if the design of the "Tee" intersection for the dual CVS hoses is a "Y" that minimizes the flow loss from each leg of the "Y," if each leg of the dual exhaust collection system is approximately equal in length (± 1 foot), and if the dilution area at the end of each leg is approximately equal. In addition, the CVS flow capacity shall be such that the entrance flow velocity for each leg of the dual exhaust system is sufficient to entrain all of the vehicle's exhaust from each tailpipe.
- (iv) Background Sample. The mixing tee shall be used to collect the background sample. The position of the mixing tee for taking the background sample shall be within 12 lateral and 12 longitudinal feet of the position during the transient driving cycle, and approximately 4 vertical feet from the floor.

- (v) Integrated Sample. A continuous dilute sample shall be provided for integration by the analytical instruments in a manner similar to the method for collecting bag samples as described in §86.109-90.

(c) **Analytical Instruments**

(1) General Requirements.

- (i) Instrument Specifications. The emission analysis system shall automatically sample, integrate, and record the specified emission values for HC, CO, CO₂, and NO_x. Performance of the analytical instruments with respect to accuracy and precision, drift, interferences, noise, etc. shall be similar to instruments used for testing under §86 Subparts B, D, and N. Analytical instruments shall perform in this manner in the full range of operating conditions in the lane environment.
- (ii) Alternative Designs. Alternative analytic equipment specifications, materials, designs, or detection methods may be allowed upon a determination by the Administrator, that for the purpose of properly conducting an approved short test, the evidence supporting such deviations will not significantly affect the proper measurement of emissions.

(2) Detection Methods and Instrument Ranges

- (i) Total Hydrocarbon Analysis. Total hydrocarbon analysis shall be determined by a flame ionization detector. If a 700 SCFM CVS is used, the analyzer calibration curve shall cover at least the range of 0 ppmC to 2,000 ppmC. Use of a different CVS flow capacity shall require an adjustment to these ranges. Appropriate documentation supporting any adjustment in ranges shall be available. The calibration curve must comply with the quality control specifications in §85.2234(d) for calibration curve generation.
- (ii) Carbon Monoxide Analysis. CO analysis shall be determined using a non-dispersive infrared analyzer. If a 700 SCFM CVS is used, CO analysis shall cover at least the range of 0 ppm to 10,000 ppm (1%). In order to meet the calibration curve requirements, two CO analyzers may be required - one from 0 to 1000 or 2000 ppm, and one from 0 to 1% CO. Use of a different CVS flow capacity shall require an adjustment to these ranges. Appropriate documentation supporting any adjustment in ranges shall be available. The calibration curve requirements and the quality control specifications in §85.2234(d) apply to both analyzers.
- (iii) Carbon Dioxide Analysis. CO₂ analysis shall be determined using an NDIR analyzer. If a 700 SCFM CVS is used, CO₂ analysis shall cover at least the range of 0 ppm to 40,000 ppm (4%). Use of a different CVS flow capacity shall require an adjustment to these ranges. Appropriate documentation supporting any adjustment in ranges shall be available. The calibration curve must comply with the quality control specifications in §85.2234(d) for calibration curve generation.
- (iv) Oxides of Nitrogen Analysis. NO_x analysis shall be determined using chemiluminescence. The NO_x measurement shall be the sum of nitrogen oxide and nitrogen dioxide. Alternatively, NO_x measurements may be made by re-calibrating the chemiluminescence analyzer in NO only mode, then running the analyzer in NO only mode and multiplying the result by 1.03. This will eliminate the need for the converter and flow balance checks in §85.2234(d)(5) and §85.2234(d)(6).

If a 700 SCFM CVS is used, the NO_x analysis shall cover at least the range of 0 ppm to 500 ppm. Use of a different CVS flow capacity shall require an adjustment to these

ranges. Appropriate documentation supporting any adjustment in ranges shall be available. The calibration curve must comply with the quality control specifications in §85.2234(d) for calibration curve generation.

- (3) System Response Requirements. Historically, continuously integrated emission analyzers have been required to have a response time of 1.5 seconds or less to 90% of a step change, where a step change was 60% of full scale or better. System response times between a step change at the probe and reading 90% of the change shall be less than 10 seconds.
- (4) Integration Requirements.
 - (i) Sampling Frequency. The analyzer voltage responses, CVS pressure(s), CVS temperature(s), dynamometer speed, and dynamometer power shall be sampled at a frequency of no less than 5 Hertz, and the voltage levels shall be averaged over 1 second intervals.
 - (ii) Time Alignment. The system shall properly time correlate each analyzer signal and the CVS signals to the driving trace.
 - (iii) Engineering Units. The one-second average analyzer voltage levels shall be converted to concentrations by the analyzer calibration curves. Corrected concentrations for each gas shall be derived by subtracting the pre-test background concentrations from the measured concentrations, according to the method in §85.2205(b). The corrected concentrations shall be converted to grams, for each second, using the equations specified in §85.2205(b) to combine the concentrations with the CVS flow over the same interval. The grams of emissions per test phase shall be determined using the equations in §85.2205(b).
 - (iv) Multiple Analyzers. When multiple analyzers are used for any constituent, the integration system shall simultaneously integrate both analyzers. The integrated values for the lowest analyzer in range shall be used for each second.
 - (v) Background Samples. For all constituents, the background concentration levels from the lowest range shall be used, including the case where multiple analyzers may have been used.
- (5) Analytical System Design.
 - (i) Materials. All materials in contact with exhaust gas prior to and throughout the measurement portion of the system shall be unaffected by and shall not affect the sample (i.e., the materials shall not react with the sample, and neither shall they taint the sample as a result of out gassing). Acceptable materials include stainless steel, Teflon, silicon rubber, and Tedlar[®].
 - (ii) System Filters. The sample system shall have an easily replaceable filter element to prevent particulate matter from reducing the reliability of the analytical system. The filter element shall provide for reliable sealing after filter element changes. If the sample line is heated, the filter system shall also be heated.
 - (iii) Availability of Intermediate Calculation Variables. Upon request prior to a test, all intermediate calculation variables shall be available to be downloaded to electronic files or hard copy. These variables shall include those that calculate the vehicle emission test results, perform emission analyzer and dynamometer function checks, and perform quality assurance and quality control measurements.

Evaporative System Equipment Specifications**(a) General Requirements**

- (1) Equipment Design. Automated and computerized test systems shall be used for the evaporative system tests wherever they are appropriate. Pass/fail decisions shall be made automatically. The systems shall be tamper resistant and designed to avoid damage to the vehicle during installation, testing, and removal.
- (2) Alternative Systems. Alternative purge, pressure, or gas cap test equipment specifications or designs may be proposed by a State if they are supported by data and approved in advance by the Administrator.

(b) Evaporative System Purge Test Equipment

- (1) General Requirements. The evaporative purge analysis system shall measure the instantaneous purge flow in standard liters/minute, and shall compute the total volume of the flow in standard liters over the transient driving cycle. Qualitative methods will only provide an indication of pass or fail.
- (2) Specifications. A purge flow measurement using a totalizing flow meter shall comply with the following requirements. These specifications do not apply to qualitative methods that are yet to be developed.
 - (i) Flow Capacity. A minimum of 50 liters per minute.
 - (ii) Pressure Drop. Maximum of 16 inches of water at 50 liters per minute for the complete system including hoses necessary to connect the system to the vehicle.
 - (iii) Totaled Flow. 0 to 100 liters of volume.
 - (iv) Response Time. 410 milliseconds maximum to 90% of a step change between approximately 2 and 10 liters per minute measured with air.
 - (v) Accuracy. A flow meter with a range of at least 0 to 50 liters per minute and $\pm 5\%$ of full scale accuracy shall be used for the measurement of purge flow.
 - (vi) Noise. The maximum noise shall be less than 0.001 liters per second.
 - (vii) Calibration Gas. Air.
- (3) Automatic Operation. Vehicle purge flow shall be monitored with a computerized system at a minimum sample rate of 1 Hz, shall automatically capture average (if sampled faster than 1 Hz) second-by-second readings, and shall automatically derive a pass/fail decision. The test sequence shall be automatically initiated when the transient driving cycle test is initiated.
- (4) Adaptability. The purge flow system shall have sufficient adapters to connect in a leak-tight manner with the variety of evaporative systems in the vehicle fleet. The purge measurement system shall not substantially interfere with purge flow.

(c) Evaporative System Pressure Test Equipment

- (1) General Requirements.

- (i) Pressurizing Gas. Nitrogen, or an equivalent non-toxic, non-greenhouse, inert gas, shall be used for pressurizing the evaporative system. Air should only be used if the pressurized vapor space is outside the combustible limits for the vehicle fuel type.
 - (ii) Automatic Operation. The process for filling the vapor space, monitoring compliance, recording data, and making a pass/fail decision shall be automatic. After the determination that the evaporative system has been filled to the specified pressure level, and upon initiation of the test, the pressure level in the evaporative system shall be recorded at a frequency of no less than 1 Hertz until the conclusion of the test.
 - (iii) Test Abort. The system shall be equipped with an abort system that positively shuts off and relieves pressure. The abort system shall be capable of being activated quickly and conveniently by the inspector should the need arise.
 - (iv) Grounding. A fillpipe pressure test must be designed to prevent electrostatic discharge that would pose a flammability risk during the test.
- (2) Adapters and Clamps.
- (i) Fuel Inlet Adapters. Adapters attached to the fuel fillpipe inlet shall be used to supply pressurized gas into the fuel tank. Adapters shall be available for at least 95 percent of the fuel inlets that are used on U.S. light duty vehicles and light duty trucks for the model years covered by the program.
 - (ii) Hose Clamp. The hose clamp used for the fuel inlet pressure test shall be designed to apply only enough pressure to close the flexible vent line between the fuel tank and canister without damaging it. The nose of the clamp shall be smooth-surfaced or otherwise designed to avoid damage to the vent line.
- (3) Pressure Gauge. The device for measuring pressure shall have a minimum range of 0 to 28 inches of water and an accuracy of ± 0.3 inches of water, or 2% of point, whichever is greater.
- (d) Gas Cap Test Equipment**
- (1) General Requirements.
- (i) Alternative Designs. Leak testers failing gas caps with a test standard below 60 cc/min at 30 in. WC are permissible provided they do not falsely fail gas caps designed to meet vehicle manufacturer OEM specifications, are repeatable and accurate in a centralized I/M environment, and demonstrate quantifiable reductions in real world mass emissions. OEM leak rates for individual manufacturers are proprietary. Information submitted to EPA shows some vehicle manufacturers had maximum leak rates up to 20 cc/min at 30 inches of WC.
 - (ii) Gas Cap Adapters. The gas cap tester shall accommodate at least 95 percent of the gas caps that are used on U.S. light duty vehicles and trucks for the model years covered by the gas cap test program.
 - (iii) Pressurizing Gas. Air, Nitrogen, or an equivalent non-toxic, non-greenhouse, inert gas, shall be used for pressurizing the gas cap tester.
 - (iv) Automatic Operation. The process for making a pass/fail decision shall be as automated as is reasonable. The minimum desired output signal is a qualitative indication of a passing or failing gas cap.

- (v) Over-Pressurization. The tester shall control the supply pressure of the gas used for pressure decay, direct flow measurement, or flow comparison methods and prevent over-pressurization.
- (2) Gas Cap Tester. Gas cap testers employing internal reference orifices, or pressure measurement devices, shall be traceable to NIST flow or pressure measurement standards.
- (i) Range. The tester shall identify passing gas caps with a leak rate equal to or less than 60 cc/min of air at 30 inches of WC, and failing caps with leak rates more than 60 cc/min at 30 inches of WC at reference conditions of 70F and 1 atm.
 - (ii) Filter. A serviceable air filter shall be incorporated upstream of flow orifices.
 - (iii) Power Supply. Battery powered testers shall be equipped with an automatic shutoff and a low-battery indicator.
 - (iv) Accuracy. Pressure decay, direct flow measurement, or flow comparison methods shall be accurate to ± 3 cc/min at the 60 cc/min flow standard.
 - (v) Reference Caps and Orifices. NIST traceable reference passing fuel caps or orifices of nominal 52-56 cc/min, and NIST traceable reference failing fuel caps or orifices of nominal 64-68 cc/min shall be supplied with the tester for daily verification tests.
 - (vi) Head Space. Pressure decay methods shall employ a head space sized to produce correct results at the 60 cc/min at 30 in. WC standard.

(a) **General Requirements**

- (1) Manufacturers' Recommendations. Manufacturers' recommendations for equipment installation, calibration, and maintenance, shall be followed.
- (2) Statistical Process Control. SPC tracking methods shall be established for appropriate equipment checks and custom diagnostic or verification tests.
- (3) Modifications to Quality Control Requirements. Changes to the type or frequency of the quality checks are permitted provided they are based on SPC analysis, or data from experimental studies.

(b) **Dynamometer**

- (1) Dynamometer Manufacturer Recommendations
 - (i) Minimum Requirements. The dynamometer manufacturer's requirements for periodic diagnostic checks, calibration, scheduled maintenance, and recommended quality control monitoring shall be followed.
 - (ii) Warm-up Requirements. The dynamometer manufacturer's procedure for insuring proper warm-up over a 35 to 110°F temperature range shall be followed.
- (2) Coast Down Testing
 - (i) Frequency. Dynamometers with electric and mechanical inertia simulation shall receive a daily unloaded (vehicle off the dynamometer) coast down check over the range of 60 to 10 mph. This daily check shall be run at alternating combinations of inertia and road load settings. Dynamometers using only mechanical flywheels for inertia simulation shall also receive additional weekly coast down checks to properly characterize the friction at other combinations of flywheel weights. The number of these coast downs shall be established based on the dynamometer design and quality control monitoring.
 - (ii) Load Settings. Inertia and power absorber settings shall be representative of actual vehicle test conditions, and shall result in nominal coast down times of 20 seconds when time is measured between 55 and 45 mph, and 10 seconds when time is measured between 22 and 18 mph. Inertia settings for clutchable flywheel dynamometers are discretionary but should attempt to be above and below the base inertia of the dynamometer and represent high and low inertia weight vehicles.
 - (iii) Quality Control Limits. Actual control limits for the coast down tests shall be established by statistical process control practices. At minimum, the 55 to 45 mph and 22 to 18 mph coastdown times shall be within ±1 second, and ± 0.5 seconds, respectively, of the theoretical coastdown time based on the following equation:

$$t = \frac{(0.5 * ETW / 32.2) * (V_I^2 - V_F^2)}{550 * HP}$$

Where: t = The coastdown time in seconds

ETW = The Equivalent Test Weight in pounds

V_I = The initial roll velocity in feet/second

V_F = The final roll velocity in feet/second

IHP = The dynamometer indicated horsepower

An alternative to the ± 1 or ± 0.5 second limit is to perform an unloaded coastdown from 60 to 10 mph and reduce the speed/time data to produce a polynomial relationship between horsepower (or force) versus time. The measured horsepower curve shall be within ± 0.25 horsepower or $\pm 3\%$ of point, whichever is greatest.

Dynamometers which exceed specific SPC limits or the coast down limits presented above, shall be removed from service until corrective action is taken to assure the dynamometer is performing satisfactorily.

(3) Parasitic Loss Checks

- (i) Frequency. Checks of the parasitic loss curve shall be conducted at a frequency recommended by the dynamometer manufacturer, as required by inspection of quality control data, or as necessary following service to the dynamometer.
- (ii) Quality Control Limits. Parasitic loss measurements shall be measured between 10 and 60 mph. Identification of outlier data shall be established by examination of quality control data.

Dynamometers which exceed dynamometer specific SPC limits for parasitic loss checks shall be removed from service until corrective action is taken to ensure the dynamometer is performing satisfactorily.

(4) Roll Speed.

- (i) Frequency. Weekly checks of the roll speed measurement system shall be made, or at intervals recommended by the dynamometer manufacturer, or as required by inspection of quality control data, or as necessary following service to the dynamometer.
- (ii) Quality Control Limits. If roll speed checks are conducted, the measured roll speed shall agree to within ± 0.1 mph of the calibration standard. Dynamometers which exceed the 0.1 mph limit shall be removed from service until corrective action is taken to ensure the dynamometer is performing satisfactorily.

(5) Acceptance Criteria

- (i) General. Prior to dynamometer acceptance, the dynamometer shall demonstrate compliance with the design criteria for the load cell accuracy, power absorber curve accuracy, roll geometry, dynamometer simulation error, electric inertia response time, parasitic loss measurement, and safety requirements. These criteria are specified in §85.2226(a).
- (ii) Base Inertia Verification. The base inertia of dynamometers shall be verified before dynamometer acceptance. The base inertia weight plus individual prime weights shall be verified for dynamometers which simulate inertia with mechanical flywheels. The

specified base inertia shall agree with acceptance testing measurements within ± 10 pounds.

- (iii) Independent Speed and Distance Verification. An independent method of verifying dynamometer roll speed and distance measurement accuracy shall be performed before dynamometer acceptance to ensure compliance with the specifications in §85.2226(a)(5)(v).

(c) **Constant Volume Sampler**

- (1) Flow Calibration. The flow of the CVS shall be calibrated at six flow rates upon initial installation, 6 months following installation, and every 12 months thereafter. SPC tracer gas injection data may be used to verify CVS flow in lieu of the annual calibration requirement. This data shall be made available to EPA upon request. The flow rates shall include the nominal rated flow-rate and a rate below the rated flow-rate for both critical flow venturis and subsonic venturis, and a flow-rate above the rated flow for sub-sonic venturis. The flow calibration points shall cover the range of variation in flow that typically occurs when testing. A complete calibration shall be performed following repairs to the CVS that could affect flow.
- (2) System Check. CVS flow calibration at the nominal CVS design flow shall be checked once per day using a procedure equivalent to that in §86.119(c). Deviations greater than $\pm 4\%$ shall result in automatic lockout of official testing until corrected. At the State's discretion, the frequency of this may be reduced to weekly.
- (3) Cleaning Flow Passages. The sample probe shall be checked at least once per month, and cleaned if necessary in order to maintain proper sample flow. CVS venturi passages shall be checked once per year and cleaned if necessary.
- (4) Probe Flow. The indicator identifying the presence of proper probe flow for the system design (e.g., proportional flow for CFV systems, minimum flow for time correlation of different analyzers) shall be checked on a daily basis. Lack of proper flow shall require corrective action.
- (5) Leak Check. The vacuum portion of the sample system shall be checked for leaks on a daily basis and each time the system is serviced.
- (6) System Response Time Check. The response time of each analyzer shall be checked upon initial installation and after each repair or modification to the flow system that would reasonably be expected to affect the response time, and at least once per week. The check shall include the complete sample system from the sample probe to the analyzer. Statistical process control shall be used to monitor compliance and establish quality control limits. At a minimum, response time measurements that deviate significantly from the average response time for all CVS systems designed to the same specification in the program shall require corrective action before testing may resume.
- (7) Mixing Tee Acceptance Test.
 - (i) Static Pressure Requirement. The design of the mixing tee shall be evaluated by running the transient driving cycle on at least two vehicles, representing the high and low ends of engine displacement and inertia. Changes in the static tailpipe pressure with and without CVS, measured on a second-by-second basis within 3 inches of the end of the tailpipe, shall not exceed ± 1.0 inch of water.
 - (ii) Single Exhaust System. The ability of the mixing tee design to capture all of the exhaust as a vehicle moves laterally from one extreme position on the dynamometer to the other extreme shall be evaluated with back-to-back testing of three vehicles,

representing the high and low ends of engine displacement and inertia. The back-to-back testing shall be done with the mixing tee at the tailpipe and with an airtight connection to the tailpipe (i.e., the mixing tee will be effectively moved downstream, as in typical FTP testing). The difference in carbon-balance fuel economy between the mixing tee located at the vehicle and the positive connection shall be no greater than 5%.

- (iii) Dual Exhaust System. The design of the dual exhaust system shall be evaluated with back-to-back testing of three vehicles, representing the high and low ends of engine displacement and inertia, with an airtight connection to the tailpipe (i.e., the mixing tee will be effectively moved downstream, as in typical FTP testing, for these qualification tests). The difference in carbon-balance fuel economy between the two methods shall be no greater than 5%.

(d) Analysis System

(1) Calibration Curve Generation.

- (i) Initial Installation Calibration. Upon initial installation, calibration curves shall be generated for each analyzer. If an analyzer has more than one measurement transducer, each transducer shall be considered as a separate analyzer in the analysis system for the purposes of curve generation and analysis system checks.
- (ii) Complete Range Calibration. The calibration curve shall consider the entire range of the analyzer as one curve.
- (iii) Calibration Point Spacing. When both a low range analyzer and a high range analyzer are used for a single gas (e.g., CO), the high range analyzer shall use at least 5 calibration points plus zero in the lower portion of the high range scale corresponding to approximately 100% of the full-scale value of the low range analyzer. For all analyzers, at least 5 calibration points shall be used to define the calibration curve above the 5 lower calibration points. The calibration zero gas shall be used to set the analyzer to zero.

Alternatively, gas dividers may be used to generate a 10-point calibration curve employing equally spaced points.

- (iv) Calibration Curve Fits. The calibration curves generated shall be a polynomial of the best fit and no greater than 4th order, and shall fit the data within $\pm 2.0\%$ at each calibration point as specified in §86.120-90, §86.122-78, §86.123-78, and §86.124-78.
 - (v) Mid-scale Verification. Each curve shall be verified for each analyzer with a confirming calibration standard between 15-80% of full scale that is not used for curve generation. Each confirming standard shall be measured by the curve within 2.5%.
- (2) Spanning Frequency. The zero and up-scale span points shall be checked at 3 hour intervals following the daily mid-scale curve check specified in §85.2234(d)(4) and adjusted if necessary. If the up-scale span point drifts by more than 2.0% from the previous check official testing shall be prevented and corrective action shall be taken to bring the system into compliance. If the zero point drifts by more than 2 ppmC HC, 1 ppm NO_x, 10 ppm CO, or 40 ppm CO₂, official testing shall be prevented and corrective action shall be taken to bring the system into compliance, or the unit may be zeroed prior to each test.
- (3) Limit Check. The tolerance on the adjustment of the up-scale span point shall be 0.4% of point. A software algorithm to perform the zero and span adjustment and subsequent calibration curve

adjustment shall be used. Cumulative software up-scale zero and span adjustments greater than $\pm 10\%$ from the latest calibration curve shall cause official testing to be prevented and corrective action shall be taken to bring the system into compliance. Zero and span potentiometers on the analyzer may be used between calibrations to minimize software corrections; however, a zero and span check shall be performed after any adjustment of a potentiometer.

- (4) Daily Calibration Checks. The curve for each analyzer shall be checked and adjusted to correctly read zero using a working zero gas, and an up-scale span gas within the tolerance in §85.2234(d)(3), and then by reading a mid-scale span gas within 2.5% of point, on each operating day prior to vehicle testing. If the analyzer does not read the mid-scale span point within 2.5% of point, the analyzer shall automatically be prevented from official testing. The up-scale span gas concentration for each analyzer may be up to 90% of full scale, and the mid-point concentration shall correspond to approximately 15% of full scale.
- (5) Monthly NO_x Converter Checks. The converter efficiency of the NO₂ to NO converter shall be checked on a monthly basis. The check shall be equivalent to §86.123-78 (for reference see TSD Form 305-01) except that the concentration of the NO gas shall be in the range of 75-400 ppm. Alternative methods may be used if approved by the Administrator.

This check is not required if the measurements of NO only are being performed per 85.2226(c)(2)(iv) with the NO_x analyzer run in NO only mode.

- (6) Monthly NO/NO_x Flow Balance. The flow balance between the NO and NO_x test modes shall be checked monthly. The check may be combined with the NO_x converter check as illustrated in EPA NVFEL Form 305-01.

This check is not required if the measurements of NO only are being performed per 85.2226(c)(2)(iv) with the NO_x analyzer run in NO only mode.

- (7) Monthly Calibration Checks. The basic calibration curve shall be verified monthly by the same procedure used to generate the curve in §85.2234(d)(1), and to the same tolerances.
- (8) FID Check.
- (i) FID Optimization. Upon initial operation, and after maintenance to the detector, each FID shall be checked, and adjusted if necessary, for proper peaking and characterization using the procedures described in SAE Paper No. 770141 or by analyzer manufacturer recommended procedures.
- (ii) Methane Response. The response of each FID to a methane concentration of approximately 50 ppm CH₄ shall be checked once per month. If the response is outside of the range of 1.00 to 1.30, corrective action shall be taken to bring the FID response within this range. The response shall be computed by the equation in §85.2234(d)(8)(iii). The frequency of this check may be reduced by providing 1 year of data for each analyzer that demonstrates less frequent checks are acceptable. If less frequent checks are used, the response check data shall be made available to EPA upon request.
- (iii) Methane Response Definition. Ratio of Methane Response = FID response to CH₄ gas in ppmC / ppm CH₄ in the cylinder.
- (9) Mid-Span or Cross-Checks. On a quarterly basis, and whenever gas bottles are changed, each analyzer in a given facility shall analyze a sample of a test gas. The test gas used for these cross checks shall be a 1% NIST traceable mid-span bottle and the same bottle shall be used for all

analyzers at a given facility. The analyzer shall read this mid-span gas within 2.5% of the labeled value or the analyzer shall be taken out of service.

Alternatively, all gas bottles entering a facility shall be verified using a master bench and NIST traceable SRM, CRM, NTRM, or RGM gases. Quarterly checks would then be performed on each analyzer using three points at 25%, 50%, and 75% of full scale.

- (10) Interference Test. The CO analyzer shall be checked for water vapor interference prior to initial service. The interference limits in this paragraph shall apply to analyzers used with a CVS of 700 SCFM or greater. For analyzers used with lower flow rate CVS units, the allowable interference response shall be proportionately adjusted downward.
 - (i) CO Analyzer. A CO instrument will be considered to be essentially free of CO₂ and water vapor interference if its response to a mixture of 3% CO₂ in N₂ which has been bubbled through water at 20°C produces an equivalent CO response, as measured on the most sensitive CO range, which is less than 1% of full scale.

(e) **Gases**

- (1) General Requirements. Gas blends may contain up to three of any of the following components: HC, CO, CO₂, and NO. The HC component shall be propane. The diluent for blends containing HC shall be air. The diluent for blends containing NO shall be N₂. CO and CO₂ may be used with either air or N₂ as the diluent. Blends containing four interest components may be used only if approved by the Administrator. Blends containing NO₂ shall also require approval by the Administrator prior to use, except if used to perform the NO_x converter check specified in §85.2234(d)(5). Any interference effects between components in a gas blend shall be addressed in the quality control and quality assurance process. When a gas audit of the analytical system is performed, the auditor shall indicate whether CO₂ is present in the audit gas mixture prior to performing the audit.
- (2) Calibration Gases. Gases used to generate and check calibration curves shall be traceable to a NIST SRM, CRM, NTRM, or RGM and have a stated uncertainty to within 1% of the standard by Gas Comparison methods. Calibration zero gas shall be used when using a gas divider to generate intermediary calibration gases.
- (3) Span Gases. Gases used for up-scale span adjustment, cross-checks, and for mid-scale span checks shall be traceable to NIST SRM, CRM, NTRM, or RGM and have a stated uncertainty to within 2% of the standard by Gas Comparison methods. Span gas concentrations shall be verified immediately after a monthly calibration curve check and before being put into service. If the reading on the span gases exceeds 2.5% of the label value, the system or gases shall be taken out of service until corrective action is taken. When a gas divider is used to generate span gases, the diluent gas shall not have impurities any greater than the working zero gas.
- (4) Calibration Zero Gas. The impurities in the calibration zero gas shall not exceed 0.1 ppmC, 0.5 ppm CO, 1 ppm CO₂, and 0.1 ppm NO. Calibration zero grade air shall be used for the FID zero calibration gas. Calibration zero grade nitrogen or calibration zero grade air shall be used for CO, CO₂, and NO_x zero calibration gases.
- (5) Working Zero Gas. The impurities in working zero grade gases shall not exceed 1 ppmC, 2 ppm CO, 400 ppm CO₂, and 0.3 ppm NO_x. Working zero grade air or calibration zero grade air shall be used for the FID zero span gas. Working or calibration zero grade nitrogen or air shall be used for CO, CO₂, and NO_x zero span gases.

- (6) FID Fuel. The fuel for the FID shall consist of a mixture of 40% ($\pm 2\%$) hydrogen, and the balance helium. The FID oxidizer shall be zero grade air, which can consist of artificial air containing 18 to 21 mole percent of oxygen.
- (7) Gas Naming Protocol. Gases used for calibration or auditing shall be named according to a written established practice that has been approved by the Administrator.

(f) Overall System Performance

- (1) Emission Levels. For each test lane, the average, median, 10th percentile and 90th percentile of the composite emissions (HC, CO, CO₂, and NO_x) measured shall be monitored on a monthly basis. Differences in the monthly average of greater than $\pm 10\%$ by any one lane from the facility-average or combined facility-average, or by any one facility from the combined facility-average shall require an investigation to determine whether the single lane or facility has a systematic equipment or operating error or difference. Where it can be determined that the averages from one facility (or facilities) are offset from the average of the other facilities based on the mix of vehicles tested, the $\pm 10\%$ limit shall be compared to the expected offset. If systematic equipment or operating errors or differences causing the offset are found, such errors shall be corrected. The sample period may be adjusted to assure that a reasonably random sample of vehicles was tested in each lane.
- (2) Pass/Fail Status. The average number of passing vehicles and the average number of failing vehicles shall be monitored monthly for each test lane. Differences in the monthly average of greater than $\pm 15\%$ by any one lane from the facility-average or combined facility-average, or by any one facility from the combined facility-average shall require an investigation to determine whether the single lane or facility has a systematic equipment or operating error or difference. Where it can be determined that the averages from one facility (or facilities) are offset from the average of the other facilities based on the mix of vehicles tested, the $\pm 15\%$ limit shall be compared to the expected offset. If systematic equipment or operating errors or differences causing the offset are found, such errors shall be corrected. The sample period may be adjusted to assure that a reasonably random sample of vehicles was tested in each lane.

(g) Control Charts

- (1) General Requirements. Control charts and Statistical Process Control theory shall be used to determine, forecast, and maintain performance of each test lane, each facility, and all facilities in a given network. The control charts shall cover the performance of key parameters in the test system. When key parameters approach control chart limits, close monitoring of such systems shall be initiated and corrective actions shall be taken when needed to prevent such systems from exceeding control chart limits. If any key parameter exceeds the control chart limits, corrective action shall be taken to bring the system into compliance. The control chart limits specified are those values listed for the test procedures, the equipment specifications, and the quality control specifications that cause a test to be voided or require equipment to be removed from service. These values are "fit for use" limits, unlike a strict interpretation of SPC control chart theory which may use tighter limits to define the process. The test facility is encouraged to apply SPC strict control chart theory to determine when equipment or processes could be improved. No action shall be required until the equipment or process exceeds the "fit for use limits" specified in this section.
- (2) Control Charts for Individual Test Lanes. In general, control charts for individual test lanes shall include parameters that will allow the cause for abnormal performance of a test lane to be pinpointed to individual systems or components. Test lane control charts shall include at a minimum:

- (i) Difference between theoretical and measured coast-down times
 - (ii) Difference between theoretical and measured CVS flow
 - (iii) Up-scale span change from last up-scale span (not required if software corrections are tracked)
 - (iv) Mathematical or software correction to the calibration curve as a result of an up-scale span change (if used)
 - (v) Difference between the analyzer response to the daily cross-check, and the test gas concentration
 - (vi) The system response time
 - (vii) FID CH₄ response ratio
 - (viii) Difference between theoretical or measured values for other parameters measured during quality assurance procedures
- (3) Control Charts for Individual Facilities. Control charts for individual facilities shall consist of facility-averages of the test lane control charts for each test lane at the facility.
- (4) Control Charts of Individual Inspectors. Control charts for individual inspectors shall include parameters that will allow the cause for abnormal performance to be evaluated. Control charts for individual inspectors shall be compared to the combined control charts for each facility and for the network.

(a) General Requirements

- (1) Manufacturers' Recommendations. Manufacturers' recommendations for equipment installation, calibration, and maintenance shall be followed.
- (2) Statistical Process Control. SPC tracking methods shall be established for appropriate equipment checks and custom diagnostic or verification tests.
- (3) Modifications to Quality Control Requirements. Changes to the type or frequency of the quality checks are permitted provided they are based on SPC analysis, or data from experimental studies.

(b) Evaporative Purge System Flow Checks

- (1) Weekly Check. On a weekly basis, the calibration of flow meters shall be checked for accuracy using an independent reference system. SPC tracking techniques shall be used to establish appropriate quality limits for the flow meters.

(c) Evaporative System Pressure Checks

- (1) Daily Checks. The pressure check system shall be pressurized to 28 ± 1 inch of WC and monitored for a loss of pressure. Pressure testing shall be stopped and corrective action shall be taken to repair the system if a loss of pressure of more than 0.4 inches of WC is observed over a 15 second period.
- (2) Bi-Weekly Check. Pressure gauges or measurement devices shall be checked on a bi-weekly basis against a reference gauge or device equal to or better than the specified performance requirements. Deviations exceeding the specified accuracy shall require corrective action.

(d) Evaporative System Gas Cap Checks

- (1) Gas Cap Tester.
 - (i) Daily Checks. The tester shall be verified daily by testing and correctly identifying passing and failing reference gas caps or flow orifices as specified in §85.2227(d)(2)(v). Reference caps and orifices shall be stored in a dirt and dust free manner to prevent clogging and changes in flow rates. Reference caps and orifices shall be stored at the same temperature as the cap tester to provide accurate flow reference.
 - (ii) Corrective Action. Gas cap testing shall be stopped and corrective action taken to repair the tester if passing and failing reference gas caps or flow orifices cannot be correctly identified.
 - (iii) Reference Caps or Orifices - Flow Checks. Independent flow bench verification of the reference gas caps and flow orifices shall be conducted before initial usage, and at six month intervals, or as recommended by the cap tester manufacturer or as suggested by analysis of quality control data. The bench flow verification results shall be traceable to NIST.
 - (iv) Comparator Orifices - Flow Checks. Internal flow standard orifices for direct flow measurement methods, or flow comparator methods, shall be traceable to a NIST reference.

(2) Gas Cap Adapters.

- (i) Leak Checks. The gas cap adapters shall be checked for visual damage daily and leak checked weekly, or by following the recommendations of the gas cap adapters supplier.

§85.2239 Test Report

(a) General Test Report Information

- (1) Vehicle Description.
 - (i) License plate number
 - (ii) Vehicle identification number
 - (iii) Weight class
 - (iv) Odometer reading
- (2) Date and Time. Date and end time of the tailpipe emission measurement test.
- (3) Identification Information. Name or identification number of the individual performing the test and the location of the test station and lane.
- (4) Warranty Provisions. For failed vehicles, a statement indicating the availability of warranty coverage as provided in Section 207 of the Clean Air Act.
- (5) Certification. A statement certifying that the short tests were performed in accordance with applicable regulations.

(b) Tests and Results

- (1) Test Types and Standards. The test report shall indicate the types of tests performed on the vehicle and the test standards for each. Test standards shall be displayed to the appropriate number of significant digits as in §85.2205(a). For the IM240 the reported standards shall be the composite test standards.
- (2) Test Scores. The test report shall show the scores for each test performed. Test scores shall be displayed to the same number of significant digits as the standards.
- (3) IM240 Scores. The reported score for the IM240 shall be in units of grams per mile and shall be selected based upon the following:
 - (i) Passing Scores - Composite IM240. If the emissions of any exhaust component on the composite IM240 are below the applicable standard in §85.2205(a), then the vehicle shall pass for that constituent and the composite score shall be reported.
 - (ii) Passing Scores - Phase 2. If the emissions of any exhaust component on the composite IM240 exceed the applicable standard in §85.2205(a) but are below the Phase 2 standard, then the vehicle shall pass for that component and the Phase 2 score shall be reported.
 - (iii) Failing Scores. If the emissions of any exhaust component on the composite IM240 exceed the applicable standard in §85.2205(a)(2) through §85.2205(a)(4) and exceed the Two Ways to Pass Standard as described in §85.2205(a)(1), then the vehicle shall fail for that component and the composite score shall be reported.
 - (iv) Emission Reporting. If a passing decision is made for all three exhaust components on the IM240 before the end of the full driving cycle according to the criteria described in §85.2205(a)(4), the passing results and reported emissions levels shall be those obtained at the time the test is terminated. Emission levels for the IM240 shall be reported in grams per mile calculated using the full IM240 mileage (not actual

mileage). The emission standards reported shall be the composite standards (i.e., not the fast-pass standards).

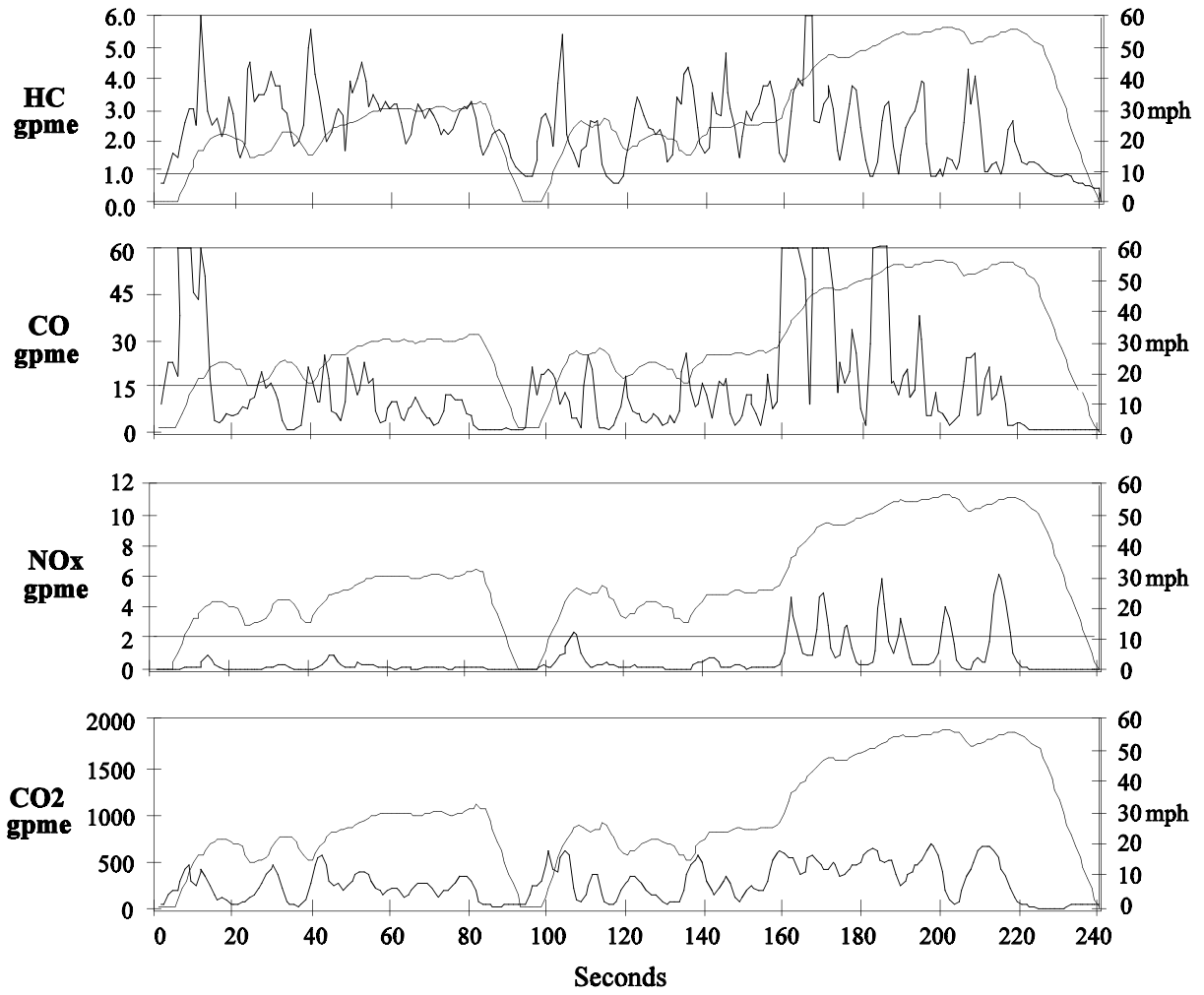
- (4) Pressure Test Scores. The score(s) for the pressure test(s) shall be reported as a change in pressure expressed in inches of water.
- (5) Test Results. The test report shall indicate the pass/fail result for each test performed and the overall result. In the case of exhaust emission tests, the report shall indicate the pass/fail status for each component for which standards apply.
- (6) Second-by-Second Measurements. For vehicles failing the IM240, a graph showing the second-by-second emission levels (see following example), for each exhaust component in grams per mile equivalent.

(c) **Recommended IM240 Second-By-Second Emissions Report**

Test Number 4719

Model Year	1988	Test Weight	3000	<u>Emission</u>	<u>Actual</u>	<u>Cut point</u>
Make	XXXX	TRLHP	14.7	HC (gpm)	2.45	0.80
Model	YYYY	Traction Control	No	CO (gpm)	23.1	15.0
Cylinders	4	ABS	No	NOx (gpm)	0.71	2.00
Transmission	Auto	Gas Cap Test	Yes	CO2 (gpm)	279	n/a
Vehicle Type	LDGV	Press Test	Yes			

The following figures provide illustrations of the recommended second-by-second emissions output.



§85.2241**Terms**

(1)	ALVW:	Adjusted Loaded Vehicle Weight: $(VCW + GVWR)/2$
(2)	CFV:	Critical Flow Venturi
(3)	CH ₄ :	Methane
(4)	CO ₂ :	Carbon dioxide
(5)	CO:	Carbon monoxide
(6)	CRM:	Certified Reference Material
(7)	CVS:	Constant Volume Sampler
(8)	ETW:	Equivalent Test Weight
(9)	FID:	Flame Ionization Detector
(10)	gpm:	Grams per mile
(11)	GVWR:	Gross Vehicle Weight Rating
(12)	HC:	Hydrocarbons
(13)	HDGT:	Heavy-Duty Gasoline-powered Truck greater than 8500 pounds GVWR
(14)	hp:	Horsepower
(15)	Hz:	Cycles per Second (Hertz)
(16)	I/M:	Inspection and Maintenance
(17)	IW:	Inertia Weight
(18)	LDGV:	Light-Duty Gasoline-powered Vehicle
(19)	LVW:	Loaded Vehicle Weight: $VCW + 300$ pounds
(20)	mph:	Miles per hour
(21)	NDIR:	Non-Dispersive Infrared
(22)	NIST:	National Institute for Standards and Technology
(23)	NO ₂ :	Nitrogen Dioxide
(24)	NO:	Nitrogen Oxide
(25)	NO _x :	Oxides of Nitrogen
(26)	NVFEL:	National Vehicle and Fuel Emissions Laboratory
(27)	Obmph:	Observed dynamometer speed in mph of the loading roller, if rolls are not coupled
(28)	PLHP:	Parasitic horsepower loss at the observed dynamometer speed in mph
(29)	ppm:	parts per million by volume
(30)	ppmC:	parts per million, carbon
(31)	psi:	Pounds per square inch
(32)	RFP:	Request for Proposal
(33)	RLHP	Road Load Horsepower
(34)	rpm:	revolutions per minute
(35)	SCFM:	Standard cubic feet per minute
(36)	SPC:	Statistical Process Control
(37)	SRM:	Standard Reference Material
(38)	SSV:	Subsonic venturi
(39)	TRLHP:	Track Road-Load Horsepower
(40)	VCW:	Vehicle Curb Weight: Actual vehicle weight with standard equipment and 100% fuel fill
(41)	WC:	Pressure in inches of water column
