40 CFR Part 1066

Vehicle-Testing Procedures

DRAFT Working Document

(LD Tier III NPRM changes denoted by "track changes" – the latest set of changes, Round 7, are in gray)

2/15/13

Part 1066—Vehicle-Testing Procedures

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Deleted: 1066.836 Spot check correlation procedures for vehicles tested using a simulation of the environmental test cell for air conditioning emission testing.¶

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1066.838 Air conditioning idle test procedure.¶

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Subpart A—Applicability and General Provisions

§1066.1 Applicability.

(a) This part describes the procedures that apply to testing we require for the following vehicles:

(1) Model year 2014 and later heavy-duty highway vehicles we regulate under 40 CFR part 1037 that are not subject to chassis testing for exhaust emissions under 40 CFR part 86.

(2) Model year 2022 and later highway vehicles that are subject to chassis testing for exhaust emissions under 40 CFR part 86. See 40 CFR part 86 for provisions describing how to implement this part 1066.

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(b) The procedures of this part may apply to other types of vehicles, as described in this part and in the standard-setting part.

(c) The term "you" means anyone performing testing under this part other than EPA.

(1) This part is addressed primarily to manufacturers of vehicles, but it applies equally to anyone who does testing under this part for such manufacturers.

(2) This part applies to any manufacturer or supplier of test equipment, instruments, supplies, or any other goods or services related to the procedures, requirements, recommendations, or options in this part.

(d) Paragraph (a) of this section identifies the parts of the CFR that define emission standards and other requirements for particular types of vehicles. In this part, we refer to each of these other parts generically as the "standard-setting part." For example, 40 CFR part 1037 is the standard-setting part for heavy-duty highway vehicles and parts 86 and 600 are the standard-setting parts for light-duty vehicles. For vehicles subject to 40 CFR part 86, subpart S, references to the standard-setting part include subpart I of this part.

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(e) Unless we specify otherwise, the terms "procedures" and "test procedures" in this part include all aspects of vehicle testing, including the equipment specifications, calibrations, calculations, and other protocols and procedural specifications needed to measure emissions.

(f) For additional information regarding these test procedures, visit our Web site at www.epa.gov, and in particular http://www.epa.gov/nvfel/testing/regulations.htm.

§1066.2 Submitting information to EPA under this part.

(a) You are responsible for statements and information in your applications for certification, requests for approved procedures, selective enforcement audits, laboratory audits, production-line test reports, or any other statements you make to us related to this part 1066. If you provide statements or information to someone for submission to EPA, you are responsible for these statements and information as if you had submitted them to EPA yourself.

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(b) In the standard-setting part and in 40 CFR 1068.101, we describe your obligation to report truthful and complete information and the consequences of failing to meet this obligation. See also 18 U.S.C. 1001 and 42 U.S.C. 7413(c)(2). This obligation applies whether you submit this information directly to EPA or through someone else.

(c) We may void any certificates or approvals associated with a submission of information if we find that you intentionally submitted false, incomplete, or misleading information. For example, if we find that you intentionally submitted incomplete information to mislead EPA when requesting approval to use alternate test procedures, we may void the certificates for all engine families certified based on emission data collected using the alternate procedures. This would also apply if you ignore data from incomplete tests or from repeat tests with higher emission results.

(d) We may require an authorized representative of your company to approve and sign the submission, and to certify that all the information submitted is accurate and complete. This includes everyone who submits information, including manufacturers and others.

(e) See 40 CFR 1068.10 for provisions related to confidential information. Note however that under 40 CFR 2.301, emission data are generally not eligible for confidential treatment.

(f) Nothing in this part should be interpreted to limit our ability under Clean Air Act section 208 (42 U.S.C. 7542) to verify that vehicles conform to the regulations.

§1066.5 Overview of this part 1066 and its relationship to the standard-setting part.

(a) This part specifies procedures that can apply generally to testing various categories of vehicles. See the standard-setting part for directions in applying specific provisions in this part for a particular type of vehicle. Before using this part's procedures, read the standard-setting part to answer at least the following questions:

(1) What drive schedules must I use for testing?

(2) Should I warm up the test vehicle before measuring emissions, or do I need to measure cold-start emissions during a warm-up segment of the duty cycle?

(3) Which exhaust constituents do I need to measure? Measure all exhaust constituents that are subject to emission standards, any other exhaust constituents needed for calculating emission rates, and any additional exhaust constituents as specified in the standard-setting part. See 40 CFR 1065.5 regarding requests to omit measurement of N_2O and CH_4 for vehicles, not subject to N_2O or CH_4 emission standards.

(4) Do any unique specifications apply for test fuels?

(5) What maintenance steps may I take before or between tests on an emission-data vehicle?

(6) Do any unique requirements apply to stabilizing emission levels on a new vehicle?

(7) Do any unique requirements apply to test limits, such as ambient temperatures or pressures?

(8) [Reserved]

(9) Are there any emission standards specified at particular operating conditions or ambient conditions?

(10) Do any unique requirements apply for durability testing?

(b) The testing specifications in the standard-setting part may differ from the specifications in this part. In cases where it is not possible to comply with both the standard-setting part and this part, you must comply with the specifications in the standard-setting part. The standard-setting part may also allow you to deviate from the procedures of this part for other reasons.

(c) The following table shows how this part divides testing specifications into subparts:

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Table 1 of §1066.5—Description of Part 1066 subparts.

This subpart	Describes these specifications or procedures
Subpart A	Applicability and general provisions.
Subpart B	Equipment for testing.
Subpart C	Dynamometer specifications.
Subpart D	Coastdowns for testing.
Subpart E	How to prepare your vehicle and run an emission test.
Subpart F	How to test hybrid vehicles.
Subpart G	Test procedure calculations.
Subpart H	Cold temperature testing.
Subpart I	Exhaust emission test procedures for motor vehicles.
Subpart J	Reserved.
Subpart K	Definitions and reference material.

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§1066.10 Other procedures.

(a) Your testing. The procedures in this part apply for all testing you do to show compliance with emission standards, with certain exceptions listed in this section. In some other sections in this part, we allow you to use other procedures (such as less precise or less accurate procedures) if they do not affect your ability to show that your vehicles comply with the applicable emission standards. This generally requires emission levels to be far enough below the applicable emission standards so that any errors caused by greater imprecision or inaccuracy do not affect your ability to state unconditionally that the engines meet all applicable emission standards.

(b) Our testing. These procedures generally apply for testing that we do to determine if your vehicles comply with applicable emission standards. We may perform other testing as allowed by the Act.

(c) Exceptions. We may allow or require you to use procedures other than those specified in this part as described in 40 CFR 1065.10(c). All the test procedures noted as exceptions to the specified procedures are considered generically as "other procedures." Note that the terms "special procedures" and "alternate procedures" have specific meanings; "special procedures" are those allowed by 40 CFR 1065.10(c)(2) and "alternate procedures" are those allowed by 40 CFR 1065.10(c)(7). If we require you to request approval to use other procedures under this paragraph (c), you may not use them until we approve your request.

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§1066.15 Overview of test procedures.

This section outlines the procedures to test vehicles that are subject to emission standards.

(a) In the standard-setting part, we set emission standards in g/mile (or g/km), for the following constituents:

(1) Total oxides of nitrogen, NO_x.

(2) Hydrocarbons, HC, which may be expressed in the following ways:

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(i) Total hydrocarbons, THC.

(ii) Nonmethane hydrocarbons, NMHC, which results from subtracting methane (CH_4) from THC.

(iii) Total hydrocarbon-equivalent, THCE, which results from adjusting THC mathematically to be equivalent on a carbon-mass basis.

(iv) Nonmethane hydrocarbon-equivalent, NMHCE, which results from adjusting NMHC mathematically to be equivalent on a carbon-mass basis.

(v) Nonmethane organic gases, NMOG, which are calculated either from fully or partially speciated measurement of hydrocarbons including oxygenates, or by adjusting measured NMHC values based on fuel oxygenate properties.

(3) Particulate mass, PM.

(4) Carbon monoxide, CO.

(5) Carbon dioxide, CO_2.

(6) Methane, CH_4.

(7) Nitrous oxide, N_2O.

(8) Formaldehyde, CH_2O.

(b) Note that some vehicles may not be subject to standards for all the emission constituents identified in paragraph (a) of this section.

(c) The provisions of this part apply for chassis dynamometer testing where vehicle speed is controlled to follow a prescribed duty cycle while simulating vehicle driving through the dynamometer's road-load settings. We generally set emission standards over test intervals and/or drive schedules, as follows:

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(1) Vehicle operation. Testing involves measuring emissions and miles travelled while operating the vehicle on a chassis dynamometer. Refer to the definitions of "duty cycle" and "test interval" in §1066.1001. Note that a single drive schedule may have multiple test intervals and require weighting of results from multiple test intervals to calculate a composite distance-based emission value to compare to the standard.

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(2) Constituent determination. Determine the total mass of each constituent over a test interval by selecting from the following methods:

(i) Continuous sampling. In continuous sampling, measure the constituent's concentration continuously from raw or dilute exhaust. Multiply this concentration by the continuous (raw or dilute) flow rate at the emission sampling location to determine the constituent's flow rate. Sum the constituent's flow rate continuously over the test interval. This sum is the total mass of the emitted constituent.

(ii) Batch sampling. In batch sampling, continuously extract and store a sample of raw or dilute exhaust for later measurement. Extract a sample proportional to the raw or dilute exhaust flow rate, as applicable. You may extract and store a proportional sample of exhaust in an appropriate container, such as a bag, and then measure HC, CO, and NO_x concentrations in the container after the test interval. You may deposit PM from proportionally extracted exhaust onto an appropriate substrate, such as a filter. In this case, divide the PM by the amount of filtered exhaust to calculate the PM concentration. Multiply batch sampled concentrations by the total (raw or dilute) flow from which it was extracted during the test interval. This product is the total mass of the emitted constituent.

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(iii) Combined sampling. You may use continuous and batch sampling simultaneously during a test interval, as follows:

(A) You may use continuous sampling for some constituents and batch sampling for others.

(B) You may use continuous and batch sampling for a single constituent, with one being a redundant measurement, subject to the provisions of 40 CFR 1065.201.

(d) Refer to the standard-setting part for calculations to determine g/mile emission rates.

(e) You must use good engineering judgment for all aspects of testing under this part. While the regulation highlights several specific cases where good engineering judgment is especially relevant, the requirement to use good engineering judgment is not limited to those provisions where we specifically re-state this requirement.

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§1066.20 Units of measure and overview of calculations.

(a) System of units. The procedures in this part follow both conventional English Units and the International System of Units (SI), as detailed in NIST Special Publication 811, which we incorporate by reference in §1066.1010. Except where specified, equations work with any system of units. Where the equations depend on the use of specific units, these units are identified.

(b) Units conversion. Use good engineering judgment to convert units between measurement systems as needed. For example, if you measure vehicle speed as kilometers per hour and we specify a precision requirement in terms of miles per hour, convert your measured kilometer per hour value to miles per hour before comparing it to our specification. The following conventions are used throughout this document and should be used to convert units as applicable:

(1) 1 hp = 33,000 ft·lbf/min = 550 ft·lbf/s = 0.7457 kW.

(2) 1 lbf = 32.174 ft·lbm/s^2 = 4.4482 N.

(3) 1 inch = 25.4 mm.

(4) 1 mile = 1609.344 m.

(5) For ideal gases, 1 µmol/mol = 1 ppm.

(6) For ideal gases, 10 mmol/mol = 1 %.

(7) Unless specified otherwise, use absolute temperature and absolute pressure.

(c) Rounding. The rounding provisions of 40 CFR 1065.20 apply for calculations in this part. This generally specifies that you round final values but not intermediate values. Use good engineering judgment to record the appropriate number of significant digits for all measurements.

(d) Interpretation of ranges. Interpret a range as a tolerance unless we explicitly identify it as an accuracy, repeatability, linearity, or noise specification. See 40 CFR 1065.1001 for the definition of tolerance. In this part, we specify two types of ranges:

(1) Whenever we specify a range by a single value and corresponding limit values above and below that value (such as X ±Y), target the associated control point to that single value (X). Examples of this type of range include "±10 % of maximum pressure", or "(30 ±10) kPa". In these examples, you would target the maximum pressure or 30 kPa, respectively.

(2) Whenever we specify a range by the interval between two values, you may target any associated control point to any value within that range. An example of this type of range is "(40 to 50) kPa".

(e) Scaling of specifications with respect to an applicable standard. Because this part 1066 applies to a wide range of vehicles and emission standards, some of the specifications in this part are scaled with respect to a vehicle's applicable standard or weight. This ensures that the specification will be adequate to determine compliance, but not overly burdensome by requiring unnecessarily high-precision equipment. Many of these specifications are given with respect to a "flow-weighted mean" that is expected at the standard or during testing. Flow-weighted mean is the mean of a quantity after it is weighted proportional to a corresponding flow rate. For example, if a gas concentration is measured continuously from the raw exhaust of an engine, its flow-weighted mean concentration is the sum of the products of each recorded concentration times its respective exhaust flow rate, divided by the sum of the recorded flow rates. As another example, the bag concentration from a CVS system is the same as the flow-weighted mean concentration, because the CVS system itself flow-weights the bag concentration.

§1066.25 Recordkeeping.

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The procedures in this part include various requirements to record data or other information. Refer to the standard-setting part and §1066.695 regarding recordkeeping requirements. You must promptly send us organized, written records in English if we ask for them. We may review them at any time.

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Subpart B—Equipment, Measurement Instruments, Fuel, and Analytical Gas Specifications

§1066.101 Overview.

(a) This subpart addresses equipment related to emission testing, as well as test fuels and analytical gases. This section addresses emission sampling and analytical equipment, test fuels, and analytical gases.

(b) The provisions of 40 CFR part 1065 specify engine-based procedures for measuring emissions. Except as specified otherwise in this part, the provisions of 40 CFR part 1065 apply for testing required by this part as follows:

(1) The provisions of 40 CFR part 1065, subpart B, describe equipment specifications for exhaust dilution and sampling systems; these specifications apply for testing under this part as described in §1066.110.

(2) The provisions of 40 CFR part 1065, subpart C, describe specifications for measurement instrument; these specifications apply for testing under this part as described in §1066.120.

(3) The provisions of 40 CFR part 1065, subpart D, describe specifications for measurement instrument calibrations and verifications; these specifications apply for testing under this part as described in §1066.130.

(4) The provisions of 40 CFR part 1065, subpart H, describe specifications for fuels, engine fluids, and analytical gases; these specifications apply for testing under this part as described in §1066.145.

(5) The provisions of 40 CFR part 1065, subpart I, describe specifications for testing with oxygenated fuels; these specifications apply for NMOG determinations as described in §1066.665.

(c) The provisions of this subpart are intended to specify systems that can very accurately and precisely measure emissions from motor vehicles such as light-duty vehicles. To the extent that this level of accuracy and/or precision is not necessary for testing highway motorcycles or nonroad vehicles, we may waive or modify the specifications and requirements of this part for testing these other vehicles, consistent with good engineering judgment. For example, it may be appropriate to allow the use of a hydrokinetic dynamometer that is not able to meet all the performance specifications described in this subpart.

§1066.110 Equipment specifications.

(a) This section specifies equipment related to emission testing, other than measurement instruments. This equipment includes two broad categories—dynamometers (described further in subpart C of this part) and emission-sampling hardware. Other related sections in this subpart identify measurement instruments (§1066.120), describe how to evaluate the performance of these instruments (§§1066.130 and 1066.137), describe how to calibrate a CVS (§1066.140), specify engine fluids and analytical gases (§1066.145), and specify requirements for analyzer interference and quench verification (§1066.150).

(b) The following equipment specifications apply for testing under this part:

(1) Sampling system connections. Connect a vehicle's exhaust system to any dilution stage as follows:

(i) Minimize laboratory exhaust tubing lengths. You may use a total length of laboratory tubing up to 4 m. However, you may use a total length of laboratory tubing up to 10 m if you insulate

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(4) The provisions of 40 CFR part 1065, subpart J, describe how to measure emissions from vehicles operating outside of a laboratory, except that provisions related to measuring engine work do not apply.

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or heat the tubing to minimize the temperature difference between the exhaust gas and the tubing wall over the course of the emission test. The laboratory exhaust tubing starts at the end of the vehicle's tailpipe. The laboratory exhaust tubing ends at the first sample point or the point of first dilution. You may use flexible laboratory exhaust tubing at any location in the laboratory exhaust system. For multiple-tailpipe configurations where the tailpipes combine into a single flow path for emission sampling, the start of the laboratory exhaust tubing may be taken at the last joint where the exhaust flow first becomes a single, combined flow.

(ii) You may insulate or heat any laboratory exhaust tubing.

(iii) Use laboratory exhaust tubing materials that are smooth-walled and not chemically reactive with exhaust constituents. For measurements involving PM, tubing materials must also be electrically conductive. Stainless steel is an acceptable material for any measurements. You may use short sections of nonconductive flexible tubing to connect a PM sampling system to the vehicle's tailpipe; use good engineering judgment to limit the amount of nonconductive surface area exposed to the vehicle's exhaust.

(iv) We recommend that you use laboratory exhaust tubing that has either a wall thickness of less than 2 mm or is air gap-insulated to minimize temperature differences between the wall and the exhaust.

(v) Seal your system to the extent necessary to ensure that any remaining leaks do not affect your ability to demonstrate compliance with the applicable standards.

(vi) Electrically ground the entire exhaust system, with the exception of nonconductive flexible tubing, as allowed under paragraph (b)(1)(iii) of this section.

(vii) For vehicles with multiple tailpipes, route the exhaust into a single flow. To ensure mixing of the multiple exhaust streams before emission sampling, you may configure the exhaust system with turbulence generators, such as orifice plates or fins, to achieve good mixing. We recommend a minimum Reynolds number, *Re#*, of 4000 for the combined exhaust stream, where *Re#* is based on the inside diameter of the combined flow at the first sampling point. *Re#* is defined in 40 CFR 1065.640.

(2) Provisions from 40 CFR part 1065. Use equipment specifications in sections 40 CFR 1065.140 through 40 CFR 1065.190, except as follows:

(i) For PM background measurement, the following provisions apply instead of the analogous provisions in 40 CFR 1065.140(b):

(A) You need not measure PM background for every test. You may apply PM background correction using a moving-average background value as long as your background PM sample media (e.g., filters) were all made by the same manufacturer from the same material . Use good engineering judgment to determine how many background samples make up the moving average and how frequently to update those values. For example, you might take one background sample per week and average that sample into previous background values, maintaining five observations for each calculated average value. Background sampling time should be representative of the test interval duration to which the background correction is applied.

(B) You may sample background PM from the dilution tunnel at any time before or after an emission test using the same sample train used during the emission test. For this background sampling, the dilution tunnel blower must be turned on, the vehicle must be disconnected from the exhaust transfer tube, and the exhaust transfer tube must be capped.

(C) Using good engineering judgment, the duration of your background sample does not need to be the same as the test cycle in which you are applying the background correction.

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(D) Your background correction may not exceed 5 µg or 5 % of the net PM mass expected at the standard, whichever is greater.
(ii) The provisions of 40 CFR 1065.140(d)(2)(iv) do not apply.
(iii) For PM samples, configure dilution systems using the following limits:
(A) Control the dilution air temperature as described in 40 CFR 1065.140(e)(1), except that the temperature may set to (15 to 52) °C. Use good engineering judgment to control PM sample temperature as required under 40 CFR 1065.140(e)(4).
(B) Apply the provisions of this paragraph (b)(2)(iii)(B) instead of 40 CFR 1065.140(e)(2). Add dilution air to the raw exhaust such that the overall dilution factor of diluted exhaust to raw exhaust, as determined in Eq. 1066.620-2 or 1066.620-3, is within the range of (7:1 to 20:1). Compliance with this dilution factor range may be determined for an individual test interval or as a time weighted average over the entire duty cycle as determined in Eq. 1066.620-4. The maximum dilution factor limit of 20:1 does not apply for plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs), since the dilution factor is infinite when the engine is off; however we strongly recommend that you stay under the maximum dilution factor limit when the engine is running. For partial-flow sampling systems, determine dilution factor using Eq. 1066.620-3. When determining dilution factor for PM samples utilizing secondary dilution air, multiply the dilution factor by the dilution ratio of secondary dilution air to primary diluted exhaust.
(iv) In addition to the allowances in 40 CFR 1065.140(c)(6) to address aqueous condensation in the CVS, you may also heat the dilution air as described in paragraph (b)(2)(iii)(A) of this section.
(v) If you choose to dilute the exhaust by using a remote mix tee, you may use the following provisions, using good engineering judgment, provided they do not affect your ability to demonstrate compliance with the standard:
(A) You may use accordion-style or smooth-walled flexible tubing in the dilution tunnel upstream of flow or gaseous emission measurement locations.
(B) You may use smooth-walled electrically conductive flexible tubing in the dilution tunnel upstream of where PM emission measurements are made.
(C) Materials for inside surfaces are limited to 300 series stainless steel and polymer-based materials.
(D) Use good engineering judgment to ensure that the materials you choose do not cause or contribute to unrepresentative loss of PM to your sample.
(vi) Paragraph (b)(1)(vi) of this section applies instead of 40 CFR 1065.145(b).
(c) The following table summarizes the requirements of paragraph (b)(2) of this section:

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Table 1 of §1066.110–Summary of equipment specifications from 40 CFR part 1065, subpart B, that apply for chassis testing

40 CFR part 1065 references	Applicability for chassis testing under this part
40 CFR 1065.140	Use all except: 40 CFR 1065.140(b) applies as described in this section. Use 40 CFR 1065.140(c)(6), with the additional allowance described in this section. Do not use 40 CFR 1065.140(d)(2)(iv). Use 40 CFR 1065.140(e)(1) as described in this section. Do not use 40 CFR 1065.140(e)(2).
40 CFR 1065.145	Use all except 40 CFR 1065.145(b).
40 CFR 1065.150 through 1065.190	Use all.

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§1066.120 Measurement instruments.

The measurement instrument requirements in 40 CFR part 1065, subpart C, apply with the following exceptions:

(a) The provisions of §1066.122 apply instead of 40 CFR 1065.202.

(b) The provisions of 40 CFR 1065.210 and 1065.295 do not apply.

§1066.122 Data updating, recording, and control for measurement instruments.

This section specifies criteria that your test system must meet for updating and recording data. It also specifies criteria for controlling the systems related to driver demand, the dynamometer, sampling equipment, and measurement instruments.

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(a)(1) This paragraph (a)(1) applies where we specify a minimum command and control frequency that is greater than the minimum recording frequency, such as for sample flow rates from a CVS that does not have a heat exchanger. For these measurements, the rate at which you read and interpret the signal must be at least as frequent as the minimum command and control frequency. Values may be recorded at the same frequency. They may also be recorded as means of the values, provided the frequency of the mean values meets the minimum recording frequency. All values read must be either recorded or used to calculate the mean values. For example, if your system reads and controls the sample flow rate at 10 Hz, you may record these values at 10 Hz, record them at 5 Hz by averaging pairs of consecutive points together, or record them at 1 Hz by averaging five consecutive points together.

(2) For all other measured values covered by this section, you may record the values instantaneously or as mean values, consistent with good engineering judgment.

(3) You may not use rolling averages of measured values where a given measured value is included in more than one recorded mean value.

(b) Use data acquisition and control systems that can command, control, and record at the following minimum frequencies:

Table 1 of §1066.122–Data recording and control minimum frequencies

Applicable Section	Measured Values	Minimum Command and Control Frequency	Minimum Recording Frequency[a]
§1066.310 §1066.320	Vehicle speed	—	10 Hz
§1066.430	Continuous concentrations of raw or dilute analyzers	—	1 Hz
§1066.430 §1066.501	Power analyzer[b]	—	1 Hz
§1066.430	Bag concentrations of raw or dilute analyzers	—	1 mean value per test interval
40 CFR 1065.545 §1066.430	Diluted exhaust flow rate from a CVS with a heat exchanger upstream of the flow measurement	—	1 Hz
40 CFR 1065.545 §1066.430	Diluted exhaust flow rate from a CVS without a heat exchanger upstream of the flow measurement	N/A	1 Hz means
40 CFR 1065.545 §1066.430	Dilution air flow if actively controlled (for example, a partial flow PM sampler)	5 Hz	1 Hz means
40 CFR 1065.545 §1066.430	Sample flow from a CVS that has a heat exchanger	1 Hz	1 Hz
40 CFR 1065.545 §1066.430	Sample flow from a CVS that does not have a heat exchanger	5 Hz	1 Hz means
§1066.425	Ambient temperature	—	1 Hz
§1066.425	Ambient humidity	—	1 Hz
§1066.425	Heated sample system temperatures, including PM filter face	—	1 Hz

[a]1 Hz means are data reported from the instrument at a higher frequency, but recorded as a series of mean

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values at a rate of 1 Hz. [b]For power analyzers' sampling frequency, follow SAE J1711 (incorporated by reference in §1066.1010).

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§1066.130 Measurement instrument calibrations and verifications.

The measurement instrument calibration and verification requirements in 40 CFR 1065, subpart D, apply with the following exceptions:

(a) The calibration and verification provisions of 40 CFR 1065.303 do not apply for engine speed, torque, fuel rate, or intake air flow. Section 1066.133 specifies additional calibration and verification provisions that apply specifically for chassis testing.

(b) The linearity verification provisions of 40 CFR 1065.307 do not apply for engine speed, torque, fuel rate, or intake air flow. Section 1066.137 specifies additional linearity verification provisions that apply specifically for chassis testing.

(c) The provisions of §1066.220 apply instead 40 CFR 1065.310.

(d) The provisions of 40 CFR 1065.320, 1065.325, and 1065.395 do not apply.

(e) If you are measuring flow volumetrically, the provisions of §1066.140 apply instead of 40 CFR 1065.340.

(f) The provisions of §1066.150 apply instead 40 CFR 1065.350(c), 1065.355(c), 1065.370(c), and 1065.375(c).

(g) Table 1 of this section summarizes the required and recommended calibrations and verifications that are unique to testing under this part and indicates when these have to be performed. Perform other required or recommended calibration and verifications as described in 40 CFR 1065.303, with the exceptions noted in this section. Table 1 follows:

Table 1 of §1066.133–Summary of required calibration and verifications.

Type of calibration or verification	Minimum frequency[a]
40 CFR 1065.303: Flow rates	This calibration does not apply for testing under this part; see §1066.133 for alternative provisions.
40 CFR 1065.307: Linearity verification	The linearity calibrations from 40 CFR part 1065 do not apply under this part for engine speed, torque, fuel rate, or intake air flow; the linearity verification described in §1066.137 applies for the following measurements: ~~Dynamometer Speed: See §1066.220.~~ Dynamometer Torque: See §1066.220.
40 CFR 1065.310: Torque	This calibration does not apply for testing under this part; see §1066.220.
40 CFR 1065.320: Fuel flow	This calibration does not apply for testing under this part.
40 CFR 1065.325: Intake flow	This calibration does not apply for testing under this part.
40 CFR 1065.340: CVS calibration	This calibration does not apply for CVS flow meters calibrated volumetrically as described in §1066.140.
40 CFR 1065.345: Vacuum leak	Required upon initial installation of the sampling system; recommended within 35 days before the start of an emissions test and after maintenance such as pre-filter changes.
40 CFR 1065.350(c), 1065.355(c), 1065.370(c), and 1065.375(c)	These provisions do not apply for testing under this part; see §1066.150.
40 CFR 1065.395: Inertial PM balance and weighing	These verifications do not apply for testing under this part.

[a]Perform calibrations and verifications more frequently if needed to conform to the measurement system manufacturer's instructions and good engineering judgment.

§1066.137 Linearity verification.

This section describes requirements for linearity verification that are unique to testing under this part. (Note: see the definition of "linearity" in 40 CFR 1065.1001, where we explain that linearity means the degree to which measured values agree with respective reference values and that the term "linearity" is not used to refer to the shape of a measurement instrument's unprocessed response curve.) Perform other required or recommended calibration and verifications as described in 40 CFR 1065.307, with the exceptions noted in this section.

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Deleted: apply for flow rates (except intake air and fuel flow), gas division, concentration, temperature, and mass. The provisions of 40 CFR 1065.307

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(f) The provisions of 40 CFR 1065.320, 1065.325, and 1065.395 do not apply.

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§1066.133 Summary of calibrations and verifications.¶
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(a) For testing under this subpart, linearity verification under 40 CFR part 1065 is not required for speed, torque, fuel flow rate, or intake air flow.
(b) For gas analyzer linearity, you may use one of the following options:
(1) Use instrument manufacturer recommendations and good engineering judgment to select at least ten reference values, y_{refi}, that cover the range of values that you expect during testing (to prevent extrapolation beyond the verified range during emission testing). We recommend selecting zero as one of your reference values. For each range calibrated, if the deviation from a least-squares best-fit straight line is 2 % or less of the value at each data point, concentration values may be calculated by use of a single calibration factor for that range. If the deviation exceeds 2 % at any point, use the best-fit nonlinear equation that represents the data to within 2 % of each test point to determine concentration. If you use a gas divider to blend calibration gases, verify that the calibration curve produced names a calibration gas within 2 % of its certified concentration. Perform this verification between 15 and 50 % of the full scale analyzer range.
(2) Use the linearity requirements of 40 CFR 1065.307, except for CO_2 measurements used for determining fuel economy and GHG emissions for motor vehicles at or below 14,000 pounds. If you choose this linearity option, you must drift check and drift correct your emission data according to 40 CFR 1065.672.
(c) Perform linearity verifications for the following temperature measurements instead of those specified at 40 CFR 1065.307(e)(7):
(1) Test cell ambient air.
(2) Dilution air for PM sampling, including CVS, double-dilution, and partial-flow systems.
(3) PM sample.
(4) Chiller sample, for gaseous sampling systems that use thermal chillers to dry samples and that use chiller temperature to calculate dewpoint at the chiller outlet. For testing, if you choose to use the high alarm temperature setpoint for the chiller temperature as a constant value in determining the amount of water removed from the emission sample, you may verify the accuracy of the high alarm temperature setpoint using good engineering judgment without following the linearity verification for chiller temperature. We recommend that you input a simulated reference temperature signal below the alarm setpoint, increase this signal until the high alarm trips, and verify that the alarm setpoint value is no less than 2 °C below the reference value at the trip point.
(5) CVS inlet temperature.
(d) Perform linearity verifications for the following pressure measurements instead of those specified at 40 CFR 1065.307(e)(8):
(1) Exhaust back pressure.
(2) Barometric pressure.
(3) CVS inlet gage pressure or absolute pressure transducer.
(4) Sample dryer, for gaseous sampling systems that use either osmotic-membrane or thermal chillers to dry samples. For your testing, if you choose to use a low alarm pressure setpoint for the sample dryer pressure as a constant value in determining the amount of water removed from the emission sample, you may verify the accuracy of the low alarm pressure setpoint using good engineering judgment without following the linearity verification for sample dryer pressure. We recommend that you input a reference pressure signal above the alarm setpoint, decrease this signal until the low alarm trips, and verify that the alarm setpoint value is no more than 4 kPa above the reference value at the trip point.

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(e) When following procedures or practices that we incorporate by reference in §1066.1010, you must meet the linearity requirements given by the procedure or practice for any analytical instruments not covered under 40 CFR 1065.307, such as GC-FID or HPLC.

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§1066.140 Diluted exhaust flow calibration.

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(a) Overview. This section describes how to calibrate flow meters for diluted exhaust constant-volume sampling (CVS) systems. You may follow the molar flow calibration procedures in 40 CFR 1065.340 instead of the procedures in this section.

(b) Scope and frequency. Perform this calibration while the flow meter is installed in its permanent position, except as allowed in paragraph (c) of this section. Perform this calibration after you change any part of the flow configuration upstream or downstream of the flow meter that may affect the flow-meter calibration. Perform this calibration upon initial CVS installation and whenever corrective action does not resolve a failure to meet the diluted exhaust flow verification (i.e., propane check) in 40 CFR 1065.341.

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(c) Ex-situ CFV and SSV calibration. You may remove a CFV or SSV from its permanent position for calibration as long as it meets the requirements in 40 CFR 1065.340(c).

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(d) Reference flow meter. Calibrate a CVS flow meter using a reference flow meter such as a subsonic venturi flow meter, a long-radius ASME/NIST flow nozzle, a smooth approach orifice, a laminar flow element, a set of critical flow venturis, or an ultrasonic flow meter. Use a reference flow meter that reports quantities that are NIST-traceable within ±1 % uncertainty. Use this reference flow meter's response to flow as the reference value for CVS flow-meter calibration.

(e) Configuration. Calibrate the system with any upstream screens or other restrictions that will be used during testing and that could affect the flow ahead of the reference flow meter. You may not use any upstream screen or other restriction that could affect the flow ahead of the reference flow meter, unless the flow meter has been calibrated with such a restriction.

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(f) PDP calibration. Calibrate a positive-displacement pump (PDP) to determine a flow-versus-PDP speed equation that accounts for flow leakage across sealing surfaces in the PDP as a function of PDP inlet pressure. Determine unique equation coefficients for each speed at which you operate the PDP. Calibrate a PDP flow meter as follows:

(1) Connect the system as shown in Figure 1 of this section.

(2) Leaks between the calibration flow meter and the PDP must be less than 0.3 % of the total flow at the lowest calibrated flow point; for example, at the highest restriction and lowest PDP-speed point.

(3) While the PDP operates, maintain a constant temperature at the PDP inlet within ±2 % of the mean absolute inlet temperature, $\bar{T}_{in}$.

(4) Set the PDP speed to the first speed point at which you intend to calibrate.

(5) Set the variable restrictor to its wide-open position.

(6) Operate the PDP for at least 3 min to stabilize the system. Continue operating the PDP and record the mean values of at least 30 seconds of sampled data of each of the following quantities:

(i) The mean flow rate of the reference flow meter, $\bar{\dot{Q}}_{ref}$. This may include several measurements of different quantities, such as reference meter pressures and temperatures, for calculating $\bar{\dot{Q}}_{ref}$.

(ii) The mean temperature at the PDP inlet, $\bar{T}_{in}$.

(iii) The mean static absolute pressure at the PDP inlet, $\bar{p}_{in}$.

(iv) The mean static absolute pressure at the PDP outlet, $\bar{p}_{out}$.

(v) The mean PDP speed, $\bar{f}_{nPDP}$.

(7) Incrementally close the restrictor valve to decrease the absolute pressure at the inlet to the PDP, p_{in}.

(8) Repeat the steps in paragraphs (e)(6) and (7) of this section to record data at a minimum of six restrictor positions ranging from the wide-open restrictor position to the minimum expected pressure at the PDP inlet.
(9) Calibrate the PDP by using the collected data and the equations in §1066.650(a).
(10) Repeat the steps in paragraphs (e)(6) through (9) of this section for each speed at which you operate the PDP.
(11) Use the equations in §1066.652(a) to determine the PDP flow equation for emission testing.
(12) Verify the calibration by performing a CVS verification (i.e., propane check) as described in 40 CFR 1065.341.
(13) Ensure that the lowest inlet pressure tested during calibration is at least as low as the lowest PDP inlet pressure that will occur during emission testing. You may not use the PDP below the lowest inlet pressure tested during calibration.
(g) SSV calibration. Calibrate a subsonic venturi (SSV) to determine its discharge coefficient, C_d, for the expected range of inlet pressures. Calibrate an SSV flow meter as follows:
(1) Connect the system as shown in Figure 1 of this section.
(2) Verify that any leaks between the calibration flow meter and the SSV are less than 0.3 % of the total flow at the highest restriction.
(3) Start the blower downstream of the SSV.
(4) While the SSV operates, maintain a constant temperature at the SSV inlet within ±2 % of the mean absolute inlet temperature, $\bar{T}_{in}$.

(5) Set the variable restrictor or variable-speed blower to a flow rate greater than the greatest flow rate expected during testing. You may not extrapolate flow rates beyond calibrated values, so we recommend that you make sure the Reynolds number, $Re^{\#}$, at the SSV throat at the greatest calibrated flow rate is greater than the maximum $Re^{\#}$ expected during testing.
(6) Operate the SSV for at least 3 min to stabilize the system. Continue operating the SSV and record the mean of at least 30 seconds of sampled data of each of the following quantities:

(i) The mean flow rate of the reference flow meter, $\bar{\dot{Q}}_{ref}$. This may include several measurements of different quantities, such as reference meter pressures and temperatures, for calculating $\bar{\dot{Q}}_{ref}$.

(ii) The mean temperature at the venturi inlet, $\bar{T}_{in}$.

(iii) The mean static absolute pressure at the venturi inlet, $\bar{p}_{in}$.

(iv) Static differential pressure between the static pressure at the venturi inlet and the static pressure at the venturi throat, $\Delta\bar{p}_{SSV}$.

(7) Incrementally close the restrictor valve or decrease the blower speed to decrease the flow rate.
(8) Repeat the steps in paragraphs (g)(6) and (7) of this section to record data at a minimum of ten flow rates.

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(9) Determine a functional form of C_d versus $Re^{\#}$ by using the collected data and the equations in §1066.650(b).
(10) Verify the calibration by performing a CVS verification (i.e., propane check) as described in 40 CFR 1065.341 using the new C_d versus $Re^{\#}$ equation.
(11) Use the SSV only between the minimum and maximum calibrated flow rates.
(12) Use the equations in §1066.652(b) to determine SSV flow during a test.
(h) CFV calibration. The calibration procedure described in this paragraph (h) establishes the value of the calibration coefficient at measured values of pressure, temperature and air flow. Calibrate a critical-flow venturi (CFV) to verify its calibration coefficient, K_v, at the lowest expected static differential pressure between the CFV inlet and outlet. Calibrate a CFV flow meter as follows:
(1) Connect the system as shown in Figure 1 of this section.
(2) Verify that any leaks between the calibration flow meter and the CFV are less than 0.3 % of the total flow at the highest restriction.
(3) Start the blower downstream of the CFV.
(4) While the CFV operates, maintain a constant temperature at the CFV inlet within ±2 % of the mean absolute inlet temperature, $\bar{T}_{in}$.
(5) Set the variable restrictor to its wide-open position. Instead of a variable restrictor, you may alternately vary the pressure downstream of the CFV by varying blower speed or by introducing a controlled leak. Note that some blowers have limitations on nonloaded conditions.
(6) Operate the CFV for at least 3 min to stabilize the system. Continue operating the CFV and record the mean values of at least 30 seconds of sampled data of each of the following quantities:
(i) The mean flow rate of the reference flow meter, $\bar{\dot{Q}}_{ref}$. This may include several measurements of different quantities, such as reference meter pressures and temperatures, for calculating $\bar{\dot{Q}}_{ref}$.
(ii) The mean temperature at the venturi inlet, $\bar{T}_{in}$.
(iii) The mean static absolute pressure at the venturi inlet, $\bar{p}_{in}$.
(iv) The mean static differential pressure between the CFV inlet and the CFV outlet, $\Delta\bar{p}_{CFV}$.
(7) Incrementally close the restrictor valve or decrease the downstream pressure to decrease the differential pressure across the CFV, $\Delta\bar{p}_{CFV}$.
(8) Repeat the steps in paragraphs (f)(6) and (7) of this section to record mean data at a minimum of ten restrictor positions, such that you test the fullest practical range of $\Delta\bar{p}_{CFV}$ expected during testing. We do not require that you remove calibration components or CVS components to calibrate at the lowest possible restriction.
(9) Determine K_v and the lowest allowable pressure ratio, r, according to §1066.650.
(10) Use K_v to determine CFV flow during an emission test. Do not use the CFV below the lowest allowed r, as determined in §1066.650.
(11) Verify the calibration by performing a CVS verification (i.e., propane check) as described in 40 CFR 1065.341.
(12) If your CVS is configured to operate multiple CFVs in parallel, calibrate your CVS using one of the following methods:

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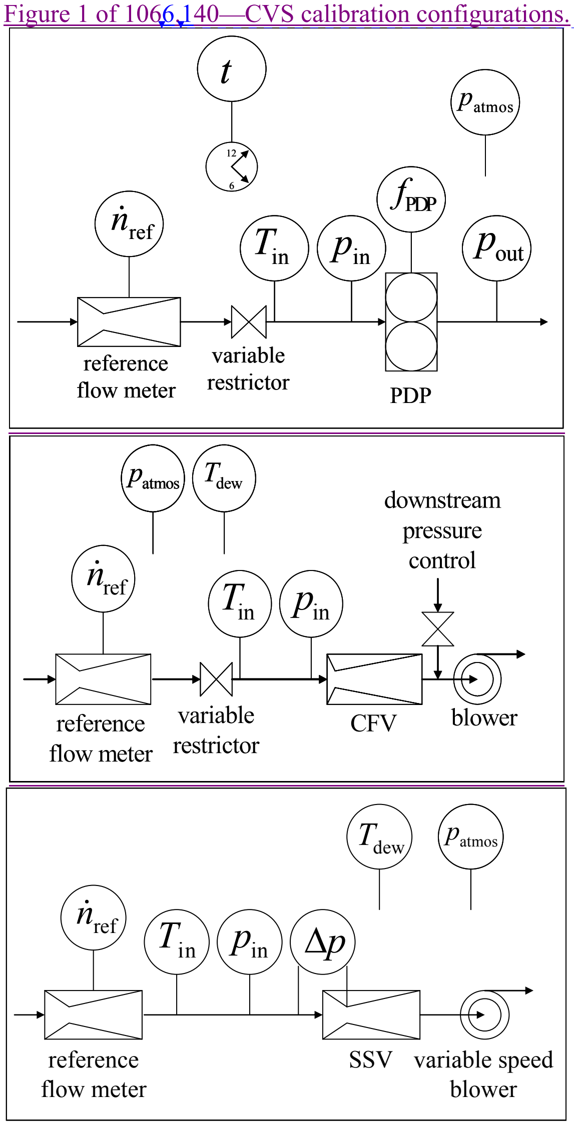
(i) Calibrate every combination of CFVs according to this section and §1066.650(c). Refer to §1065.652(c) for instructions on calculating flow rates for this option.
(ii) Calibrate each CFV according to this section and §1066.650. Refer to §1066.652 for instructions on calculating flow rates for this option.
(i) Ultrasonic flow meter calibration. [Reserved]

Figure 1 of 1066.140—CVS calibration configurations.



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§1066.145 Test fuel, engine fluids, analytical gases, and other calibration standards.

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(a) Test fuel. Use test fuel as specified in the standard-setting part, or as specified in 40 CFR part 1065, subpart H, if it is not specified in the standard-setting part.

(b) Lubricating oil. Use lubricating oil as specified in 40 CFR 1065.740. For two-stroke engines that involve a specified mixture of fuel and lubricating oil, mix the lubricating oil with the fuel according to the manufacturer's specifications.

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(c) Coolant. For liquid-cooled engines, use coolant as specified in 40 CFR 1065.745.

(d) Analytical gases. Use analytical gases that meet the requirements of 40 CFR 1065.750.

(e) Mass standards. Use mass standards that meet the requirements of 40 CFR 1065.790.

§1066.150 Analyzer interference and quench verification limit.

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Analyzers must meet the interference and quench verification limits in the following table on the lowest instrument range that will be used during emission testing, instead of those specified in 40 CFR part 1065, subpart D:

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Table 1 of §1066.150–Analyzer interference and quench verification limits.

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Verification	Limit
40 CFR 1065.350	±2 % of full scale
40 CFR 1065.355	±2 % of full scale
40 CFR 1065.370	±2 % of full scale
40 CFR 1065.375	±2 % of the flow-weighted mean concentration of N_2O expected at the standard

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Subpart C—Dynamometer Specifications

§1066.201 Dynamometer overview.
This subpart addresses chassis dynamometers and related equipment.

§1066.210 Dynamometers.
(a) General requirements. A chassis dynamometer typically uses electrically generated load forces combined with its rotational inertia to recreate the mechanical inertia and frictional forces that a vehicle exerts on road surfaces (known as “road load”). Load forces are calculated using vehicle-specific coefficients and response characteristics. The load forces are applied to the vehicle tires by rolls connected to motor/absorbers. The dynamometer uses a load cell to measure the forces the dynamometer rolls apply to the vehicle’s tires.
(b) Accuracy and precision. The dynamometer’s output values for road load must be NIST-traceable. We may determine traceability to a specific international standards organization to be sufficient to demonstrate NIST-traceability. The force-measurement system must be capable of indicating force readings as follows:
(1) For dynamometer testing of vehicles at or below 20,000 pounds GVWR, the dynamometer force-measurement system must be capable of indicating force readings during a test to a resolution of ±0.05 % of the maximum load-cell force simulated by the dynamometer or ±9.8 N (±2.2 lbf), whichever is greater.
(2) For dynamometers testing of vehicles above 20,000 pounds GVWR the force-measurement system must be capable of indicating force readings during a test to a resolution of ±0.05 % of the maximum load-cell force simulated by the dynamometer or ±39.2 N (±8.8 lbf), whichever is greater.
(c) Test cycles. The dynamometer must be capable of fully simulating vehicle performance over applicable test cycles for the vehicles being tested as referenced in the corresponding standard-setting part, including operation at the combination of inertial and road-load forces corresponding to maximum road load conditions and maximum simulated inertia at the highest acceleration rate experienced during testing.
(d) Component requirements. The following specifications apply:
(1) The nominal roll diameter must be 120 cm or greater. The dynamometer must have an independent drive roll for each drive axle as tested under §1066.410(g), except that two drive axles may share a single drive roll. Use good engineering judgment to ensure that the dynamometer roll diameter is large enough to provide sufficient tire-roll contact area to avoid tire overheating and power losses from tire-roll slippage.
(2) Measure and record force and speed at 10 Hz or faster. You may convert measured values to 1-Hz, 2-Hz, or 5-Hz values before your calculations, using good engineering judgment.
(3) The load applied by the dynamometer simulates forces acting on the vehicle during normal driving according to the following equation:

$$FR_i = A + B \cdot v_i + C \cdot v_i^2 + M \cdot \frac{v_i - v_{i-1}}{t_i - t_{i-1}}$$

Eq. 1066.210-1

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(1) For vehicles with a gross vehicle weight rating (GVWR) at or below 14,000 lbs, the dynamometer must be able to fully simulate a driving schedule with a maximum speed of 36 m/s (80 mph) and a maximum acceleration rate of 3.6 m/s^2 (8 mph/s) in two-wheel drive and four-wheel drive configurations.
(2) For vehicles with GVWR above 14,000 lbs, the dynamometer must be able to fully simulate a driving schedule with a maximum speed of 29 m/s (65 mph) and a maximum acceleration rate of 1.3 m/s^2 (3 mph/s) in either two-wheel drive or four-wheel drive configurations.
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FR = total road-load force to be applied at the surface of the roll. The total force is the sum of the individual tractive forces applied at each roll surface.
i = a counter to indicate a point in time over the driving schedule. For a dynamometer operating at 10-Hz intervals over a 600-second driving schedule, the maximum value of *i* should be 6,000.
A = constant value representing the vehicle's frictional load in lbf or newtons. See subpart D of this part.
B = coefficient representing load from drag and rolling resistance, which are a function of vehicle speed, in lbf/mph or N·s/m. See subpart D of this part.
v = linear speed at the roll surfaces as measured by the dynamometer, in mph or m/s. Let $v_{i-1} = 0$ for $i = 0$.
C = coefficient representing aerodynamic effects, which are a function of vehicle speed squared, in lbf/mph^2 or N·s^2/m^2. See subpart D of this part.
M = mass of vehicle in lbm or kg. For vehicles at or below 14,000 pounds GVWR, determine the vehicle's mass based on equivalent test weight (ETW) as specified in §1066.810 and set dynamometer inertia simulation as specified in §1066.410(h). For vehicles above 14,000 pounds GVWR, determine the vehicle's mass based on the test weight, taking into account the effect of rotating axles, as specified in §1066.310(b)(7) and dividing the weight by the acceleration due to gravity as specified in 40 CFR 1065.630, consistent with good engineering judgment.
t = elapsed time in the driving schedule as measured by the dynamometer, in seconds. Let $t_{i-1} = 0$ for $i = 0$.
(4) We recommend that a dynamometer capable of testing vehicles at or below 20,000 pounds GVWR be designed to apply an actual road-load force within ±1 % or ±9.8 N (±2.2 lbf) of the reference value, whichever is greater. Dynamometers that do not fully meet this specification may be used consistent with good engineering judgment. For example, slightly higher errors may be permissible during highly transient operation for vehicles with a GVWR above 8500 pounds.
(e) Dynamometer manufacturer instructions. This part specifies that you follow the dynamometer manufacturer's recommended procedures for things such as calibrations and general operation. If you perform testing with a dynamometer that you manufactured or if you otherwise do not have these recommended procedures, use good engineering judgment to establish the additional procedures and specifications we specify in this part, unless we specify otherwise. Keep records to describe these recommended procedures and how they are consistent with good engineering judgment, including any quantified error estimates.

§1066.215 Summary of verification and calibration procedures for chassis dynamometers.
(a) Overview. This section describes the overall process for verifying and calibrating the performance of chassis dynamometers.
(b) Scope and frequency. The following table summarizes the required and recommended calibrations and verifications described in this subpart and indicates when they must occur:

Table 1 of §1066.215–Summary of required dynamometer calibrations and verifications.

Type of calibration or verification	Minimum frequency[a]
§1066.220: Linearity verification	Speed: Upon initial installation, within 370 days before testing, and after major maintenance. Torque (load): Upon initial installation and after major maintenance.
§1066.225: Roll runout and diameter verification	Upon initial installation and after major maintenance.
§1066.230: Time verification	Upon initial installation and after major maintenance.

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§1066.235: Speed measurement verification	Upon initial installation, within 370 days before testing, and after major maintenance.
§1066.240: Torque (load) transducer verification	Upon initial installation, within 7 days of testing, and after major maintenance.
§1066.245: Response time verification	Upon initial installation, within 370 days before testing, and after major maintenance.
§1066.250: Base inertia verification	Upon initial installation and after major maintenance.
§1066.255: Parasitic loss verification	Upon initial installation, after major maintenance, and upon failure of a verification in §1066.270 or §1066.280.
§1066.260: Parasitic friction compensation evaluation	Upon initial installation, after major maintenance, and upon failure of a verification in §1066.270 or §1066.280.
§1066.265: Acceleration and deceleration verification	Upon initial installation and after major maintenance.
§1066.270: Unloaded coastdown verification	Upon initial installation, within 7 days of testing, and after major maintenance.
§1066.280 Dynamometer readiness verification	Upon initial installation, within 1 day before testing, and after major maintenance.

[a]Perform calibrations and verifications more frequently, according to measurement system manufacturer instructions and good engineering judgment.

(c) Automated dynamometer verifications and calibrations. In some cases, dynamometers are designed with internal diagnostic and control features to accomplish the verifications and calibrations specified in this subpart. You may use these automated functions instead of following the procedures we specify in this subpart to demonstrate compliance with applicable requirements, consistent with good engineering judgment.
(d) Sequence of verifications and calibrations. Upon initial installation and after major maintenance, perform the verifications and calibrations in the same sequence as noted in Table 1 of this section, except that you may perform speed linearity verification after the verifications in §§1066.225 and 1066.230. At other times, you may need to perform specific verifications or calibrations in a certain sequence, as noted in this subpart. If you perform major maintenance on a specific component, you are required to perform verifications and calibrations only on components or parameters that are affected by the maintenance.
(e) Corrections. Unless the regulation directs otherwise, if the dynamometer fails to meet any specified calibration or verification, make any necessary adjustments or repairs such that the dynamometer meets the specification before running a test. Repairs required to meet specifications are generally considered major maintenance under this part.

§1066.220 Linearity verification for chassis dynamometer systems.

(a) Scope and frequency. Perform linearity verification for dynamometer speed and torque at least as frequently as indicated in Table 1 of §1066.215. The intent of linearity verification is to determine that the system responds accurately and proportionally over the measurement range of interest. Linearity verification generally consists of introducing a series of at least 10 reference values to a measurement system. The measurement system quantifies each reference value. The measured values are then collectively compared to the reference values by using a least-squares linear regression and the linearity criteria specified in Table 1 of this section.
(b) Performance requirements. If a measurement system does not meet the applicable linearity criteria in Table 1 of this section, correct the deficiency by re-calibrating, servicing, or replacing components as needed. Repeat the linearity verification after correcting the deficiency to ensure that the measurement system meets the linearity criteria. Before you may use a measurement system that does not meet linearity criteria, you must demonstrate to us that the deficiency does not adversely affect your ability to demonstrate compliance with the applicable standards.

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(c) Procedure. Use the following linearity verification protocol, or use good engineering judgment to develop a different protocol that satisfies the intent of this section, as described in paragraph (a) of this section:

(1) In this paragraph (c), the letter "y" denotes a generic measured quantity, the superscript over-bar denotes an arithmetic mean (such as $\bar{y}$), and the subscript "$_{ref}$" denotes the known or reference quantity being measured.

(2) Operate the dynamometer system at the specified operating conditions. This may include any specified adjustment or periodic calibration of the dynamometer system.

(3) Set dynamometer speed and torque to zero.

(4) Verify the dynamometer speed or torque signal based on the dynamometer manufacturer's recommendations.

(5) After verification, check for zero speed and torque. Use good engineering judgment to determine whether or not to rezero or re-verify speed and torque before continuing.

(6) For both speed and torque, use the dynamometer manufacturer's recommendations and good engineering judgment to select reference values, y_{refi}, that cover a range of values that you expect would prevent extrapolation beyond these values during emission testing. We recommend selecting zero speed and zero torque as reference values for the linearity verification.

(7) Use the dynamometer manufacturer's recommendations and good engineering judgment to select the order in which you will introduce the series of reference values. For example, you may select the reference values randomly to avoid correlation with previous measurements and to avoid the influence of hysteresis; you may select reference values in ascending or descending order to avoid long settling times of reference signals; or you may select values to ascend and then descend to incorporate the effects of any instrument hysteresis into the linearity verification.

(8) Set the dynamometer to operate at a reference condition.

(9) Allow time for the dynamometer to stabilize while it measures the reference values.

(10) At a recording frequency of at least 1 Hz, measure speed and torque values for 30 seconds and record the arithmetic mean of the recorded values, $\bar{y}_i$. Refer to 40 CFR 1065.602 for an example of calculating an arithmetic mean.

(11) Repeat the steps in paragraphs (c)(8) though (10) of this section until you measure speeds and torques at each of the reference settings.

(12) Use the arithmetic means, $\bar{y}_i$, and reference values, y_{refi}, to calculate least-squares linear regression parameters and statistical values to compare to the minimum performance criteria specified in Table 1 of this section. Use the calculations described in 40 CFR 1065.602. Using good engineering judgment, you may weight the results of individual data pairs (i.e., (y_{refi}, $\bar{y}_i$)), in the linear regression calculations. Table 1 follows:

Table 1 of §1066.220–
Dynamometer measurement systems that require linearity verifications

Measurement system	Quantity	Linearity criteria			
		$\lvert y_{min}(a_1-1)+a_0 \rvert$	a_1	SEE	r^2
Speed	v	$\leq 0.05\ \% \cdot v_{max}$	0.98-1.02	$\leq 2\ \% \cdot v_{max}$	≥ 0.990
Torque (load)	T	$\leq 1\ \% \cdot T_{max}$	0.99-1.01	$\leq 1\ \% \cdot T_{max}$	≥ 0.990

(d) Reference signals. Generate reference values for the linearity-verification protocol in paragraph (c) of this section as described for speed and torque in 40 CFR 1065.307(d).

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§1066.225 Roll runout and diameter verification procedure.

(a) Overview. This section describes the verification procedure for roll runout and roll diameter. Roll runout is a measure of the variation in roll radius around the circumference of the roll.

(b) Scope and frequency. Perform these verifications upon initial installation and after major maintenance that could affect roll surface finish or dimensions (such as resurfacing or polishing).

(c) Roll runout procedure. Verify roll runout based on the following procedure, or an equivalent procedure based on good engineering judgment:

(1) Perform this verification with laboratory and dynamometer temperatures stable and at equilibrium. Release the roll brake and shut off power to the dynamometer. Remove any dirt, rubber, rust, and debris from the roll surface. Mark measurement locations on the roll surface using a permanent marker. Mark the roll at a minimum of four equally spaced locations across the roll width; we recommend taking measurements every 150 mm across the roll. Secure the marker to the deck plate adjacent to the roll surface and slowly rotate the roll to mark a clear line around the roll circumference. Repeat this process for all measurement locations.

(2) Measure roll runout using an indicator with a probe that allows for measuring the position of the roll surface relative to the roll centerline as it turns through a complete revolution. The indicator must have some means of being securely mounted adjacent to the roll. The indicator must have sufficient range to measure roll runout at all points, with a minimum accuracy and precision of ±0.025 mm. Calibrate the indicator according to the instrument manufacturer's instructions.

(3) Position the indicator adjacent to the roll surface at the desired measurement location. Position the shaft of the indicator perpendicular to the roll such that the point of the indicator is slightly touching the surface of the roll and can move freely through a full rotation of the roll. Zero the indicator according to the instrument manufacturer's instructions. Avoid distortion of the runout measurement from the weight of a person standing on or near the mounted dial indicator.

(4) Slowly turn the roll through a complete rotation and record the maximum and minimum values from the indicator. Calculate runout as the difference between these maximum and minimum values.

(5) Repeat the steps in paragraphs (c)(3) and (4) of this section for all measurement locations.

(6) The roll runout must be less than 0.254 mm (0.0100 inches) at all measurement locations.

(d) Diameter procedure. Verify roll diameter based on the following procedure, or an equivalent procedure based on good engineering judgment:

(1) Prepare the laboratory and the dynamometer as specified in paragraph (c)(1) of this section.

(2) Measure roll diameter using a Pi Tape®. Orient the Pi Tape® to the marker line at the desired measurement location with the Pi Tape® hook pointed outward. Temporarily secure the Pi Tape® to the roll near the hook end with adhesive tape. Slowly turn the roll, wrapping the Pi Tape® around the roll surface. Ensure that the Pi Tape® is flat and adjacent to the marker line around the full circumference of the roll. Attach a 2.26-kg weight to the hook of the Pi Tape® and position the roll so that the weight dangles freely. Remove the adhesive tape without disturbing the orientation or alignment of the Pi Tape®.

(3) Overlap the gage member and the vernier scale ends of the Pi Tape® to read the diameter measurement to the nearest 0.01 mm. Follow the manufacturer's recommendation to correct the measurement to 20 °C, if applicable.

(4) Repeat the steps in paragraphs (d)(2) and (3) of this section for all measurement locations.

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(5) The measured roll diameter must be within ±0.254 mm of the specified nominal value at all measurement locations. You may revise the nominal value to meet this specification, as long as you use the corrected nominal value for all calculations in this subpart.

§1066.230 Time verification procedure.
(a) Overview. This section describes how to verify the accuracy of the dynamometer's timing device.
(b) Scope and frequency. Perform this verification upon initial installation and after major maintenance.
(c) Procedure. Perform this verification using one of the following procedures:
(1) WWV method. You may use the time and frequency signal broadcast by NIST from radio station WWV as the time standard if the trigger for the dynamometer timing circuit has a frequency decoder circuit, as follows:
(i) Dial station WWV at (303) 499-7111 and listen for the time announcement. Verify that the trigger started the dynamometer timer. Use good engineering judgment to minimize error in receiving the time and frequency signal.
(ii) After at least 1000 seconds, re-dial station WWV and listen for the time announcement. Verify that the trigger stopped the dynamometer timer.
(iii) Compare the measured elapsed time, y_{act}, to the corresponding time standard, y_{ref}, to determine the time error, y_{error}, using the following equation:

$$y_{error} = \frac{y_{act} - y_{ref}}{y_{ref}} \cdot 100\ \%$$

Eq. 1066.230-1

(2) Ramping method. You may set up an operator-defined ramp function to serve as the time standard as follows:
(i) Set up the signal generator to output a marker voltage at the peak of each ramp to trigger the dynamometer timing circuit. Output the designated marker voltage to start the verification period.
(ii) After at least 1000 seconds, output the designated marker voltage to end the verification period.
(iii) Compare the measured elapsed time between marker signals, y_{act}, to the corresponding time standard, y_{ref}, to determine the time error, y_{error}, using Eq. 1066.230-1.
(3) Dynamometer coastdown method. You may use a signal generator to output a known speed ramp signal to the dynamometer controller to serve as the time standard as follows:
(i) Generate upper and lower speed values to trigger the start and stop functions of the coastdown timer circuit. Use the signal generator to start the verification period.
(ii) After at least 1000 seconds, use the signal generator to end the verification period.
(iii) Compare the measured elapsed time between trigger signals, y_{act}, to the corresponding time standard, y_{ref}, to determine the time error, y_{error}, using Eq. 1066.230-1.
(d) Performance evaluation. The time error determined in paragraph (c) of this section may not exceed ±0.001 %.

§1066.235 Speed verification procedure.
(a) Overview. This section describes how to verify the accuracy and resolution of the dynamometer speed determination. When performing this verification, you must also verify the

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dynamometer speed at any devices used to display or record vehicle speed (for example a driver's aid) is representative of the speed input from the dynamometer speed determination.

(b) Scope and frequency. Perform this verification upon initial installation, within 370 days before testing, and after major maintenance.

(c) Procedure. Use one of the following procedures to verify the accuracy and resolution of the dynamometer speed simulation:

(1) Pulse method. Connect a universal frequency counter to the output of the dynamometer's speed-sensing device in parallel with the signal to the dynamometer controller. The universal frequency counter must be calibrated according to the instrument manufacturer's instructions and be capable of measuring with enough accuracy to perform the procedure as specified in this paragraph (c)(1). Make sure the instrumentation does not affect the signal to the dynamometer control circuits. Determine the speed error as follows:

(i) Set the dynamometer to speed-control mode. Set the dynamometer speed to a value of approximately 4.5 m/s (10 mph); record the output of the frequency counter after 10 seconds. Determine the roll speed, v_{act}, using the following equation:

$$v_{act} = \frac{f \cdot d_{roll} \cdot \pi}{n}$$

Eq. 1066.235-1

Where:

f = frequency of the dynamometer speed sensing device, accurate to at least four significant figures.

d_{roll} = nominal roll diameter, accurate to the nearest 1.0 mm, consistent with §1066.225(d).

n = the number of pulses per revolution from the dynamometer roll speed sensor.

Example:

f = 2.9231 Hz = 2.9231 s^{-1}

d_{roll} = 904.40 mm = 0.90440 m

n = 1 pulse/rev

$$v_{act} = \frac{2.9231 \cdot 0.90440 \cdot \pi}{1}$$

v_{act} = 8.3053 m/s

(ii) Repeat the steps in paragraph (c)(1)(i) of this section for the maximum speed expected during testing and at least two additional evenly spaced speed points between the starting speed and the maximum speed point.

(iii) Compare the calculated roll speed, v_{act}, to each corresponding speed set point, v_{ref}, to determine values for speed error at each set point, v_{error}, using the following equation:

$$v_{error} = v_{act} - v_{ref}$$

Eq. 1066.235-2

Example:

v_{act} = 8.3053 m/s

v_{ref} = 8.3000 m/s

v_{error} = 8.3053 – 8.3000 = 0.0053 m/s

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(2) Frequency method. Install a piece of tape in the shape of an arrowhead on the surface of the dynamometer roll near the outer edge. Put a reference mark on the deck plate in line with the tape. Install a stroboscope or photo tachometer on the deck plate and direct the flash toward the tape on the roll. The stroboscope or photo tachometer must be calibrated according to the instrument manufacturer's instructions and be capable of measuring with enough accuracy to perform the procedure as specified in this paragraph (c)(2). Determine the speed error as follows:

(i) Set the dynamometer to speed control mode. Set the dynamometer speed to a speed value of approximately 4.5 m/s (10 mph). Tune the stroboscope or photo tachometer until the signal matches the dynamometer roll speed. Record the frequency. Determine the roll speed, v_{act}, using Eq. 1066.235-1, using the stroboscope or photo tachometer's frequency for f.

(ii) Repeat the steps in paragraph (c)(2)(i) of this section for the maximum speed expected during testing and at least two additional evenly spaced speed points between the starting speed and the maximum speed point.

(iii) Compare the calculated roll speed, v_{act}, to each corresponding speed set point, v_{ref}, to determine values for speed error at each set point, v_{error}, using Eq. 1066.235-2.

(d) Performance evaluation. The speed error determined in paragraph (c) of this section may not exceed ±0.02 m/s at any speed set point.

§1066.240 Torque transducer verification.

Verify torque-measurement systems by performing the verifications described in §1066.270 and 280.

§1066.245 Response time verification.

(a) Overview. This section describes how to verify the dynamometer's response time.

(b) Scope and frequency. Perform this verification upon initial installation, within 370 days before testing, and after major maintenance.

(c) Procedure. Use the dynamometer's automated process to verify response time. You may perform this test either at two different inertia settings corresponding approximately to the minimum and maximum vehicle weights you expect to test or using base inertia and two acceleration rates that cover the range of acceleration rates experienced during testing (for example 0.5 and 8 mph/s). Use good engineering judgment to select road-load coefficients representing vehicles of the appropriate weight. Determine the dynamometer's settling response time, t_s, based on the point at which there are no measured results more than 10 % above or below the final equilibrium value, as illustrated in Figure 1 of this section. The observed settling response time must be less than 100 milliseconds for each inertia setting.

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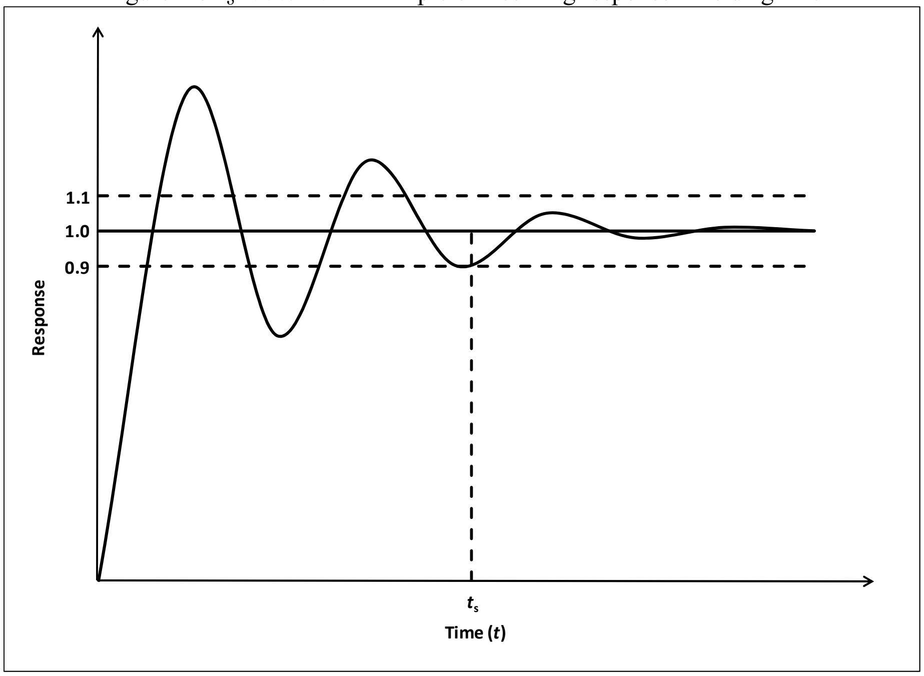
Figure 1 of §1066.245—Example of a settling response time diagram.



§1066.250 Base inertia verification.

(a) Overview. This section describes how to verify the dynamometer's base inertia.

(b) Scope and frequency. Perform this verification upon initial installation and after major maintenance (such as maintenance that could affect roll assembly inertia).

(c) Procedure. Verify the base inertia using the following procedure:

(1) Warm up the dynamometer according to the dynamometer manufacturer's instructions. Set the dynamometer's road-load inertia to zero, turning off any electrical simulation of road load and inertia so that the base inertia of the dynamometer is the only inertia present, and motor the rolls to 5 mph. Apply a constant force to accelerate the roll at a nominal rate of 1 mph/s. Measure the elapsed time to accelerate from 10 to 40 mph, noting the corresponding speed and time points to the nearest 0.01 mph and 0.01 s. Also determine average force over the measurement interval.

(2) Starting from a steady roll speed of 45 mph, apply a constant force to the roll to decelerate the roll at a nominal rate of 1 mph/s. Measure the elapsed time to decelerate from 40 to 10 mph, noting the corresponding speed and time points to the nearest 0.01 mph and 0.01 s. Also determine average force over the measurement interval.

(3) Repeat the steps in paragraphs (c)(1) and (2) of this section for a total of five sets of results at the nominal acceleration rate and the nominal deceleration rate.

(4) Use good engineering judgment to select two additional acceleration and deceleration rates that cover the middle and upper rates expected during testing. Repeat the steps in paragraphs (c)(1) through (3) of this section at each of these additional acceleration and deceleration rates.

(5) Determine the base inertia, I_b, for each measurement interval using the following equation:

$$I_b = \frac{F}{\left|\frac{v_{final} - v_{initial}}{\Delta t}\right|}$$

Eq. 1066.250-1

Where:

F = average dynamometer force over the measurement interval as measured by the dynamometer.

v_{final} = roll surface speed at the end of the measurement interval to the nearest 0.01 mph.

$v_{initial}$ = roll surface speed at the start of the measurement interval to the nearest 0.01 mph.

Δt = elapsed time during the measurement interval to the nearest 0.01 s.

Example:

F = 1.500 lbf = 48.26 ft·lbm/s^2

v_{final} = 40.00 mph = 58.67 ft/s

$v_{initial}$ = 10.00 mph = 14.67 ft/s

Δt = 30.00 s

$$I_b = \frac{48.26}{\left|\frac{58.67 - 14.67}{30.00}\right|}$$

I_b = 32.90 lbm

(6) Calculate the base inertia error, I_{berror}, for each of the thirty measured base inertia values, I_b, by comparing it to the manufacturer's stated base inertia, I_{bref}, using the following equation:

$$I_{berror} = \frac{I_{bref} - I_{bact}}{I_{bref}} \cdot 100\ \%$$

Eq. 1066.250-2

Example:

I_{bref} = 32.96 lbm

I_{bact} = 32.90 lbm (from paragraph (c)(5) of this section)

$$I_{berror} = \frac{32.96 - 32.90}{32.96} \cdot 100\ \%$$

I_{berror} = 0.18 %

(7) Determine the base inertia arithmetic mean value, $\overline{I}_b$, from the ten acceleration and deceleration interval base inertia values for each of the three acceleration/deceleration rates. Then determine the base inertia arithmetic mean value, $\overline{I}_b$, from the three acceleration/deceleration rate mean base inertia values. Calculate base inertia mean values as described in 40 CFR 1065.602(b).

(8) Calculate the inertia error for the final mean base inertia value from paragraph (c)(7) of this section. Use Eq. 1066.250-2, substituting the final mean base inertia value from paragraph (c)(7) of this section for the individual base inertia.

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(d) Performance evaluation. The dynamometer must meet the following specifications to be used for testing under this part:

(1) All base inertia errors determined under paragraph (c)(6) of this section may not exceed ±1.0 %.

(2) The mean base inertia error determined under paragraph (c)(8) of this section may not exceed ±0.20 %.

§1066.255 Parasitic loss verification.

(a) Overview. Verify and correct the dynamometer's parasitic loss. This procedure determines the dynamometer's internal losses that it must overcome to simulate road load. These losses are characterized in a parasitic loss curve that the dynamometer uses to apply compensating forces to maintain the desired road-load force at the roll surface.

(b) Scope and frequency. Perform this verification upon initial installation, after major maintenance, and upon failure of a verification in either §1066.270 or §1066.280.

(c) Procedure. Perform this verification by following the dynamometer manufacturer's specifications to establish a parasitic loss curve, taking data at fixed speed intervals to cover the range of vehicle speeds that will occur during testing. You may zero the load cell at a selected speed if that improves your ability to determine the parasitic loss. Parasitic loss forces may never be negative. Note that the torque transducers must be zeroed and spanned prior to performing this procedure.

(d) Performance evaluation. In some cases, the dynamometer automatically updates the parasitic loss curve for further testing. If this is not the case, compare the new parasitic loss curve to the original parasitic loss curve from the dynamometer manufacturer or the most recent parasitic loss curve you programmed into the dynamometer. You may reprogram the dynamometer to accept the new curve in all cases, and you must reprogram the dynamometer if any point on the new curve departs from the earlier curve by more than ±9.0 N for dynamometers capable of testing vehicles at or below 20,000 pounds GVWR or ±36.0 N (±8.0 lbf) for dynamometers not capable of testing vehicles at or below 20,000 pounds GVWR.

§1066.260 Parasitic friction compensation evaluation.

(a) Overview. This section describes how to verify the accuracy of the dynamometer's friction compensation.

(b) Scope and frequency. Perform this verification upon initial installation, after major maintenance, and upon failure of a verification in either §1066.270 or §1066.280. Note that this procedure relies on proper verification or calibration of speed and torque, as described in §§1066.235 and 1066.240. You must also first verify the dynamometer's parasitic loss curve as specified in §1066.255.

(c) Procedure. Use the following procedure to verify the accuracy of the dynamometer's friction compensation:

(1) Warm up the dynamometer as specified by the dynamometer manufacturer.

(2) Perform a torque verification as specified by the dynamometer manufacturer. For torque verifications relying on shunt procedures, if the results do not conform to specifications, recalibrate the dynamometer using NIST-traceable standards as appropriate until the dynamometer passes the torque verification. Do not change the dynamometer's base inertia to pass the torque verification.

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(3) Set the dynamometer inertia to the base inertia with the road-load coefficients A, B, and C set to 0. Set the dynamometer to speed-control mode with a target speed of 50 mph or a higher speed recommended by the dynamometer manufacturer. Once the speed stabilizes at the target speed, switch the dynamometer from speed control to torque control and allow the roll to coast for 60 seconds. Record the initial and final speeds and the corresponding start and stop times. If friction compensation is executed perfectly, there will be no change in speed during the measurement interval.

(4) Calculate the power equivalent of friction compensation error, FC_{error}, using the following equation:

$$FC_{\text{error}} = \frac{I}{2 \cdot t} \cdot \left(v_{\text{init}}^2 - v_{\text{final}}^2\right)$$

Eq. 1066.260-1

Where:

I = dynamometer inertia setting.

t = duration of the measurement interval, accurate to at least 0.01 s.

v_{init} = the roll speed corresponding to the start of the measurement interval, accurate to at least 0.05 mph.

v_{final} = the roll speed corresponding to the end of the measurement interval, accurate to at least 0.05 mph.

Example:

I = 2000 lbm = 62.16 lbf· s^2/ft

t = 60.0 s

v_{init} = 9.2 mph = 13.5 ft/s

v_{final} = 10.0 mph = 14.7 ft/s

$$FC_{\text{error}} = \frac{62.16}{2 \cdot 60.00} \cdot \left(13.5^2 - 14.7^2\right)$$

FC_{error} = –16.5 ft·lbf/s = –0.031 hp

(5) The friction compensation error may not exceed ±0.15 hp for dynamometers capable of testing vehicles at or below 20,000 pounds GVWR, or ±0.6 hp for dynamometers not capable of testing vehicles at or below 20,000 pounds GVWR.

§1066.265 Acceleration and deceleration verification.

(a) Overview. This section describes how to verify the dynamometer's ability to achieve targeted acceleration and deceleration rates. Paragraph (c) of this section describes how this verification applies when the dynamometer is programmed directly for a specific acceleration or deceleration rate. Paragraph (d) of this section describes how this verification applies when the dynamometer is programmed with a calculated force to achieve a targeted acceleration or deceleration rate.

(b) Scope and frequency. Perform this verification or an equivalent procedure upon initial installation and after major maintenance that could affect acceleration and deceleration accuracy. Note that this procedure relies on proper verification or calibration of speed as described in §1066.235.

(c) Verification of acceleration and deceleration rates. Activate the dynamometer's function generator for measuring roll revolution frequency. If the dynamometer has no such function

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generator, set up a properly calibrated external function generator consistent with the verification described in this paragraph (c). Use the function generator to determine actual acceleration and deceleration rates as the dynamometer traverses speeds between 10 and 40 mph at various nominal acceleration and deceleration rates. Verify the dynamometer's acceleration and deceleration rates as follows:

(1) Set up start and stop frequencies specific to your dynamometer by identifying the roll-revolution frequency, f, in revolutions per second (or Hz) corresponding to 10 mph and 40 mph vehicle speeds, accurate to at least four significant figures, using the following equation:

$$f = \frac{v \cdot n}{d_{\text{roll}} \cdot \pi}$$

Eq. 1066.265-1

Where:

v = the target roll speed, in inches per second (corresponding to drive speeds of 10 mph or 40 mph).

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n = the number of pulses from the dynamometer's roll-speed sensor per roll revolution.

d_{roll} = roll diameter, in inches.

(2) Program the dynamometer to accelerate the roll at a nominal rate of 1 mph/s from 10 mph to 40 mph. Measure the elapsed time to reach the target speed, to the nearest 0.01 s. Repeat this measurement for a total of five runs. Determine the actual acceleration rate for each run, a_{act}, using the following equation:

$$a_{\text{act}} = \frac{v_{\text{final}} - v_{\text{init}}}{t}$$

Eq. 1066.265-2

Where:

a_{act} = acceleration rate (decelerations have negative values).

v_{final} = the target value for the final roll speed.

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v_{init} = the setpoint value for the initial roll speed.

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t = time to accelerate from v_{init} to v_{final}.

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Example:

v_{final} = 40 mph

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v_{init} = 10 mph

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t = 30.003 s

$$a_{\text{act}} = \frac{40.00 - 10.00}{30.03}$$

a_{act} = 0.999 mph/s

(3) Program the dynamometer to decelerate the roll at a nominal rate of 1 mph/s from 40 mph to 10 mph. Measure the elapsed time to reach the target speed, to the nearest 0.01 s. Repeat this measurement for a total of five runs. Determine the actual acceleration rate, a_{act}, using Eq. 1066.265-2

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(4) Repeat the steps in paragraphs (c)(2) and (3) of this section for additional acceleration and deceleration rates in 1 mph/s increments up to and including one increment above the maximum

acceleration rate expected during testing. Average the five repeat runs to calculate a mean acceleration rate, $\overline{a}_{\text{act}}$, at each setting.

(5) Compare each mean acceleration rate, $\overline{a}_{\text{act}}$, to the corresponding nominal acceleration rate, a_{ref}, to determine values for acceleration error, a_{error}, using the following equation:

$$a_{\text{error}} = \frac{\overline{a}_{\text{act}} - a_{\text{ref}}}{a_{\text{ref}}} \cdot 100\ \%$$

Eq. 1066.265-3

Example:

$\overline{a}_{\text{act}} = 0.999$ mph/s

$a_{\text{ref}} = 1$ mph/s

$$a_{\text{error}} = \frac{0.999 - 1}{1} \cdot 100\ \%$$

$a_{\text{error}} = -0.100$ %

(d) Verification of forces for controlling acceleration and deceleration. Program the dynamometer with a calculated force value and determine actual acceleration and deceleration rates as the dynamometer traverses speeds between 10 and 40 mph at various nominal acceleration and deceleration rates. Verify the dynamometer's ability to achieve certain acceleration and deceleration rates with a given force as follows:

(1) Calculate the force setting, F, using the following equation:

$$F = I_{\text{b}} \cdot |a|$$

Eq. 1066.265-4

Where:

I_{b} = the dynamometer manufacturer's stated base inertia, in lbf·s^2/ft.

a = nominal acceleration rate, in ft/s^2.

Example:

I_{b} = 2967 lbm = 92.217 lbf· s^2/ft

a = 1 mph/s = 1.4667 ft/s^2

$$F = 92.217 \cdot |1.4667|$$

F = 135.25 lbf

(2) Set the dynamometer to road-load mode and program it with a calculated force to accelerate the roll at a nominal rate of 1 mph/s from 10 mph to 40 mph. Measure the elapsed time to reach the target speed, to the nearest 0.01 s. Repeat this measurement for a total of five runs. Determine the actual acceleration rate, a_{act}, for each run using Eq. 1066.265-2. Repeat this step to determine measured "negative acceleration" rates using a calculated force to decelerate the roll at a nominal rate of 1 mph/s from 40 mph to 10 mph. Average the five repeat runs to calculate a mean acceleration rate, $\overline{a}_{\text{act}}$, at each setting.

(3) Repeat the steps in paragraph (d)(2) of this section for additional acceleration and deceleration rates as specified in paragraph (c)(4) of this section.

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(4) Compare each mean acceleration rate, $\bar{a}_{\text{act}}$, to the corresponding nominal acceleration rate, a_{ref}, to determine values for acceleration error, a_{error}, using Eq. 1066.265-3.
(e) Performance evaluation. The acceleration error from paragraphs (c)(5) and (d)(4) of this section may not exceed ±1.0 %.

§1066.270 Unloaded coastdown verification.
(a) Overview. Use force measurements to verify the dynamometer's settings based on coastdown procedures.
(b) Scope and frequency. Perform this verification upon initial installation, within 7 days of testing, and after major maintenance.
(c) Procedure. This procedure verifies the dynamometer's settings derived from coastdown testing. For dynamometers that have an automated process for this procedure, perform this evaluation by setting the initial speed, final speed, inertial coefficients, and road-load coefficients as required for each test, using good engineering judgment to ensure that these values properly represent in-use operation. Use the following procedure if your dynamometer does not perform this verification with an automated process:
(1) Warm up the dynamometer as specified by the dynamometer manufacturer.
(2) With the dynamometer in coastdown mode, set the dynamometer inertia for the smallest vehicle weight that you expect to test and set A, B, and C road-load coefficients to values typical of those used during testing. Program the dynamometer to coast down over the dynamometer operational speed range (typically from a speed of 80 mph through a minimum speed at or below 10 mph). Perform at least one coastdown over this speed range, collecting data over each 10 mph interval.
(3) Repeat the steps in paragraph (c)(2) of this section with the dynamometer inertia and road-load coefficients set for the largest vehicle weight that you expect to test.
(4) Determine the average coastdown force, F, for each speed and inertia setting for each of the coastdowns performed using the following equation:

$$F = \frac{I \cdot (v_{\text{init}} - v_{\text{final}})}{t}$$

Eq. 1066.270-1

Where:
F = the average force measured during the coastdown for each speed interval and inertia setting, expressed in lbf· s^2/ft and rounded to four significant figures.
I = the dynamometer's inertia setting, in lbf· s^2/ft.
v_{init} = the speed at the start of the coastdown, expressed in ft/s and rounded to four significant figures.
v_{final} = the speed at the end of the coastdown interval, rounded to four significant figures.
t = coastdown time for each speed and inertia setting, accurate to at least 0.01 s.

Example:
I = 2000 lbm = 65.17 lbf · s^2/ft
v_{init} = 25 mph = 36.66 ft/s
v_{final} = 15 mph = 22.0 ft/s
t = 5.00 s

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$$F = \frac{65.17 \cdot (36.66 - 22.0)}{5.00}$$

$$F = 191.1 \text{ lbf}$$

(5) Calculate the target value of coastdown force, F_{ref}, based on the applicable dynamometer parameters for each speed and inertia setting.

(6) Compare the mean value of the coastdown force measured for each speed and inertia setting, $\bar{F}_{act}$, to the corresponding F_{ref} to determine values for coastdown force error, F_{error}, using the following equation:

$$F_{error} = \left| \frac{\bar{F}_{act} - F_{ref}}{F_{ref}} \right| \cdot 100 \text{ \%}$$

Eq. 1066.270-2

Example:

$F_{ref} = 192$ lbf

$\bar{F}_{act} = 191$ lbf

$$F_{error} = \left| \frac{191 - 192}{192} \right| \cdot 100 \text{ \%}$$

$F_{error} = 0.5$ %

(d) Performance evaluation. The coastdown force error determined in paragraph (c) of this section may not exceed the following:

(i) For vehicles at or below 20,000 pounds GVWR, calculate $F_{errormax}$ from the following formula:

$F_{errormax}$ (%) = (2.2 lbf/F_{ref})·100

Eq. 1066.270-3

Example:

$F_{ref} = 192$ lbf

$F_{errormax}$ (%) = (2.2/192)·100 = 1.14%

(ii) For vehicles above 20,000 pounds GVWR, the maximum allowable error, $F_{errormax}$, for all speed and inertia settings is ±1.0 % or ±39.2 N, whichever is greater.

(e) If the dynamometer is not able to meet this requirement, diagnose and repair the dynamometer before continuing with emission testing. Diagnosis should include performing the verifications in §1066.255 and §1066.260.

§1066.280 Dynamometer readiness verification.

(a) Overview. This section describes how to verify that the dynamometer is ready for emission testing.

(b) Scope and frequency. Perform this verification upon initial installation, within 1 day before testing, and after major maintenance.

(c) Procedure. For dynamometers that have an automated process for this verification procedure, perform this evaluation by setting the initial speed and final speed and the inertial and road-load coefficients as required for the test, using good engineering judgment to ensure that these values

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$F_{errormax}$ (%) = (2.2 lbf/F_{ref})·100

Eq. 1066.270-3

Example:

F_{ref} = 192 lbf

$F_{errormax}$ (%) = (2.2/192)·100 = 1.14%

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properly represent in-use operation. Use the following procedure if your dynamometer does not perform this verification with an automated process:
(1) With the dynamometer in coastdown mode, set the dynamometer inertia to the base inertia with the road-load coefficient A set to 20 lbf (or a force that results in a coastdown time of less than 10 minutes) and coefficients B and C set to 0. Program the dynamometer to coast down for one 10 mph interval from 55 mph down to 45 mph. If your dynamometer is not capable of performing one discrete coastdown, then coast down with preset 10 mph intervals that include a 55 mph to 45 mph interval.
(2) Perform the coastdown.
(3) Determine the coastdown force and coastdown force error using Eqs. 1066.270-1 and 1066.270-2.
(d) Performance evaluation. The coastdown force error determined in paragraph (c) of this section may not exceed the following:
(1) For vehicles at or below 20,000 pounds GVWR, ±1.0 % or ±9.8 N (±2.2 lbf), whichever is greater.
(2) For vehicles above 20,000 pounds GVWR, ±1.0 % or ±39.2 N (±8.8 lbf), whichever is greater.
(e) If the verification results fail to meet the performance criteria in paragraph (d) of this section, perform the procedure up to two additional times. If the dynamometer is consistently unable to meet the performance criteria, diagnose and repair the dynamometer before continuing with emission testing. Diagnosis should include performing the verifications in §1066.255 and §1066.260.

§1066.290 Driver's aid.
Use good engineering judgment to provide a driver's aid that facilitates compliance with the requirements of §1066.430. Verify the speed accuracy of the driver's aid as described in §1066.235.

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Subpart D—Coastdown

§1066.301 Overview of coastdown procedures.

(a) The coastdown procedures described in this subpart are used to determine the load coefficients (A, B, and C) for the simulated road-load equation in §1066.210(d)(3).

(b) The general procedure for performing coastdown tests and calculating load coefficients is described in SAE J1263 and SAE J2263 (incorporated by reference in §1066.1010). This subpart specifies certain deviations from those procedures for certain applications.

(c) Use good engineering judgment for all aspects of coastdown testing. For example, minimize the effects of grade by performing coastdown testing on reasonably level surfaces and determining coefficients based on average values from vehicle operation in opposite directions over the course.

§1066.305 Coastdown procedures for motor vehicles at or below 14,000 pounds GVWR.

For motor vehicles at or below 14,000 pounds GVWR, develop representative road-load coefficients to characterize each test vehicle. Calculate road-load coefficients by performing coastdowns using the provisions of SAE J1263 and SAE J2263 (incorporated by reference in §1066.1010). Perform coastdowns at a starting speed as specified in SAE J2263, or at the highest speed from the range of applicable duty cycles. Use the same road-load coefficients for all duty cycles. However, if your test conditions are substantially different from the conditions represented by your road-load coefficients, such as cold-temperature testing, you may use good engineering judgment to develop separate road-load coefficients.

§1066.310 Coastdown procedures for vehicles above 14,000 pounds GVWR.

This section describes coastdown procedures that are unique to vehicles above 14,000 pounds GVWR. These procedures are valid for calculating road-load coefficients for chassis and post-transmission powerpack testing and for calculating drag area (C_DA) for use in the GEM simulation tool under 40 CFR part 1037.

(a) Determine load coefficients by performing a minimum of 16 valid coastdown runs (8 in each direction).

(b) Follow the provisions of Sections 1 through 9 of SAE J1263, and SAE J2263 (incorporated by reference in §1066.1010), except as described in this paragraph (b). The terms and variables identified in this paragraph (b) have the meaning given in SAE J1263 or J2263 unless specified otherwise.

(1) The test condition specifications of SAE J1263 apply except as follows for wind and road conditions:

(i) We recommend that you do not perform coastdown testing on days for which winds are forecast to exceed 6.0 mph.

(ii) The grade of the test track or road must not be excessive (considering factors such as road safety standards and effects on the coastdown results). Road conditions should follow Section 7.4 of SAE J1263, except that road grade may exceed 0.5%. If road grade is greater than 0.02% over the length of the test surface, then the road grade as a function of distance along the length of the test surface must be incorporated into the analysis. To calculate the force due to grade use Section 11.5 of SAE J2263.

(2) Operate the vehicle at a top speed above 70 mph, or at its maximum achievable speed if it cannot reach 70 mph. If a vehicle is equipped with a vehicle speed limiter that is set for a

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maximum speed below 70 mph, you must disable the vehicle speed limiter. Start the test at or above 70 mph or at the vehicle's maximum achievable speed if it cannot reach 70 mph. Data collection must occur through a minimum speed at or below 15 mph. Data analysis for valid coastdown runs must include a maximum speed as described in this paragraph (b)(2) and a minimum speed of 15 mph.

(3) Gather data regarding wind speed and direction, in coordination with time-of-day data, using at least one stationary electro-mechanical anemometer and suitable data loggers meeting the specifications of SAE J1263, as well as the following additional specifications for the anemometer placed adjacent to the test surface:

(i) Calibrate the equipment by running the zero-wind and zero-angle calibrations within 24 hours before conducting the coastdown procedures. If the coastdown procedures are not complete 24 hours after calibrating the equipment, repeat the calibration for another 24 hours of data collection.

(ii) Record the location of the anemometer using a GPS measurement device adjacent to the test surface (approximately) at the midway distance along the test surface used for coastdowns.

(iii) Position the anemometer such that it will be at least 2.5 but not more than 3.0 vehicle widths from the test vehicle's centerline as the test vehicle passes the location of that anemometer.

(iv) Mount the anemometer at a height that is within 6 inches of half the test vehicle's maximum height.

(v) Place the anemometer at least 50 feet from the nearest tree and at least 25 feet from the nearest bush (or equivalent roadside features).

(vi) The height of the grass surrounding the stationary anemometer may not exceed 10% of the anemometer's mounted height, within a radius equal to the anemometer's mounted height.

(4) You may split runs as per Section 9.3.1 of SAE J2263, but we recommend whole runs. If you split a run, analyze each portion separately, but count the split runs as one run with respect to the minimum number of runs required.

(5) You may perform consecutive runs in a single direction, followed by consecutive runs in the opposite direction, consistent with good engineering judgment. Harmonize starting and stopping points to the extent practicable to allow runs to be paired.

(6) All valid coastdown run times in each direction must be within 2.0 standard deviations of the mean of the valid coastdown run times (from 70 mph down to 15 mph) in that direction. Eliminate runs outside this range. After eliminating these runs you must have at least eight valid runs in each direction. You may use coastdown run times that do not meet these standard deviation requirements if we approve it in advance. In your request, describe why the vehicle is not able to meet the specified standard deviation requirements and propose an alternative set of requirements.

(7) Analyze data for chassis and post-transmission powerpack testing or for use in the GEM simulation tool as follows:

(i) Follow the procedures specified in Section 10 of SAE J1263 or Section 11 of SAE J2263 to calculate coefficients for chassis and post-transmission powerpack testing.

(ii) Determine drag area, C_DA, as follows instead of using the procedure specified in Section 10 of SAE J1263:

(A) Measure vehicle speed at fixed intervals over the coastdown run (generally at 10 Hz), including speeds at or above 15 mph and at or below 70 mph. Establish the height or altitude corresponding to each interval as described in SAE J2263 if you need to incorporate the effects of road grade.

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(ii) The anemometer must have had its outputs recorded at a wind speed of 0.0 mph within 24 hours before each coastdown test in which it is used.

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(B) Calculate the vehicle's effective mass, M_e, in kg by adding 56.7 kg to the vehicle mass for each tire making road contact. This accounts for the rotational inertia of the wheels and tires.

(C) Calculate the road-load force for each measurement interval, F_i, for values of $i \geq 1$ using the following equation:

$$F_i = -M_e \cdot \frac{v_i - v_{i-1}}{\Delta t}$$

Eq. 1066.310-1

Where:

M_e = the vehicle's effective mass, expressed to the nearest 0.1 kg.

v = vehicle speed at the beginning and end of the measurement interval.

Δt = elapsed time over the measurement interval, in seconds.

(D) Plot the data from all the coastdown runs on a single plot of F_i vs. v_i^2 to determine the slope correlation, D, based on the following equation:

$$F_i - M_e \cdot g \cdot \frac{\Delta h}{\Delta s} = A_m + D \cdot v_i^2$$

Eq. 1066.310-2

Where:

g = gravitational acceleration = 9.81 m/s^2.

Δh = change in height or altitude over the measurement interval, in m. Assume $\Delta h = 0$ if you are not correcting for grade.

Δs = distance the vehicle travels down the road during the measurement interval, in m.

A_m = the calculated value of the y-intercept based on the curve-fit.

(E) Calculate drag area, C_DA, in m^2 using the following equation:

$$C_D A = \frac{2 \cdot D_{adj}}{\rho}$$

Eq. 1066.310-3

Where:

ρ = air density at reference conditions = 1.17 kg/m^3.

$$D_{adj} = D \cdot \left(\frac{\bar{T}}{293}\right) \cdot \left(\frac{98.21}{\bar{p}_B}\right)$$

Eq. 1066.310-4

$\bar{T}$ = average ambient temperature during testing, in K.

$\bar{p}_B$ = average ambient pressuring during the test, in kPa.

(8) Determine the A, B, and C coefficients identified in §1066.210 as follows:

(i) For chassis and post-transmission powerpack testing, follow the procedures specified in Section 10 of SAE J1263 or Section 12 of SAE J2263.

(ii) For the GEM simulation tool, use the following values:

A = A_m

B = 0

C = D_{adj}

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§1066.320 Dynamometer road-load setting.

Determine dynamometer road-load settings for chassis testing by following SAE J2264 (incorporated by reference in §1066.1010).

Subpart E—Preparing Vehicles and Running an Exhaust Emission Test

§1066.401 Overview.

(a) Use the procedures detailed in this subpart to measure vehicle emissions over a specified drive schedule. Different procedures may apply for criteria pollutants and greenhouse gas emissions as described in subpart I of this part or the standard-setting part. This subpart describes how to:

(1) Determine road-load power, test weight, and inertia class.

(2) Prepare the vehicle, equipment, and measurement instruments for an emission test.

(3) Perform pre-test procedures to verify proper operation of certain equipment and analyzers and to prepare them for testing.

(4) Record pre-test data.

(5) Sample emissions.

(6) Record post-test data.

(7) Perform post-test procedures to verify proper operation of certain equipment and analyzers.

(8) Weigh PM samples.

(b) The overall test consists of prescribed sequences of fueling, parking, and driving at specified test conditions. An exhaust emission test generally consists of measuring emissions and other parameters while a vehicle follows the drive schedules specified in the standard-setting part. There are two general types of test cycles:

(1) Transient cycles. Transient test cycles are typically specified in the standard-setting part as a second-by-second sequence of vehicle speed commands. Operate a vehicle over a transient cycle such that the speed follows the target values. Proportionally sample emissions and other parameters and use the calculations in 40 CFR part 1065, subpart G, or subpart G of this part to calculate emissions. The standard-setting part may specify three types of transient testing based on the approach to starting the measurement, as follows:

(i) A cold-start transient cycle where you start to measure emissions just before starting an engine that has not been warmed up.

(ii) A hot-start transient cycle where you start to measure emissions just before starting a warmed-up engine.

(iii) A hot running transient cycle where you start to measure emissions after an engine is started, warmed up, and running.

(2) Cruise cycles. Cruise test cycles are typically specified in the standard-setting part as a discrete operating point that has a single speed command.

(i) Start a cruise cycle as a hot running test, where you start to measure emissions after the engine is started and warmed up and the vehicle is running at the target test speed.

(ii) Sample emissions and other parameters for the cruise cycle in the same manner as a transient cycle, with the exception that the reference speed value is constant. Record instantaneous and mean speed values over the cycle.

§1066.407 Vehicle preparation and preconditioning.

Prepare the vehicle for testing, including measurement of evaporative and refueling emissions, as described in the standard-setting part.

§1066.410 Dynamometer test procedure.

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Deleted: (b) If testing will include measurement of refueling emissions, perform the vehicle preconditioning steps as described in 40 CFR 86.153-98the standard setting part. Otherwise, perform the vehicle preconditioning steps as described in 40 CFR 86.132-00.

(a) Dynamometer testing may consist of multiple drive cycles with both cold-start and hot-start portions, including prescribed soak times before each test interval. The standard-setting part identifies the driving schedules and the associated sample intervals, soak periods, engine startup and shutdown procedures, and operation of accessories, as applicable. Not every test interval includes all these elements.

(b) Place the vehicle onto the dynamometer without starting the engine (cold start test cycles only) or drive the vehicle onto dynamometer and position a fan that appropriately directs cooling air to the vehicle during dynamometer operation as described in this paragraph (b). This generally requires squarely positioning the fan in front of the vehicle and directing the airflow to the vehicle's radiator. Use good engineering judgment to design and configure fans to cool the test vehicle in a way that properly simulates in-use operation.

(1) For vehicles at or below 14,000 pounds GVWR, use the following cooling fan configurations as allowed under Table 1 of this section:

(i) Use a fixed-speed fan to appropriately direct cooling air to the vehicle with the engine compartment cover open. The fan capacity may not exceed 2.50 m^3/s and the fan should be placed nominally within the range of (0 to 30) cm from the front of the vehicle. If you determine that additional cooling is needed to properly represent in-use operation, use good engineering judgment to increase the fan's capacity or use additional fans, subject to our approval. When testing under this option, the engine compartment cover must be open.

(ii) Use a fixed-speed fan to direct cooling air to the vehicle with the engine compartment cover open. The fan capacity may not exceed 7.10 m^3/s and the fan should be placed nominally within the range of (0 to 60) cm from the front of the vehicle. If you determine that additional cooling is needed to properly represent in-use operation, use good engineering judgment to increase the fan's capacity or use additional fans, subject to our approval. When testing under this option, the engine compartment cover must be open.

(iii) Use a road-speed modulated fan system that achieves a linear speed of cooling air at the blower outlet that is within ±3.0 mph (±1.3 m/s) of the corresponding roll speed when vehicle speeds are between 5 and 30 mph (2.2 to 13.4 m/s), and within ±6.5 mph (±2.9 m/s) of the corresponding roll speed at higher vehicle speeds. You may limit your fan maximum linear speed to 70 mph for roll speeds in excess of 70 mph. We recommend that the cooling fan have a minimum opening of 0.2 m^2 and a minimum width of 0.8 m. The discharge nozzle shall be placed nominally within the range of (0 to 90) cm from the front of the vehicle to provide representative cooling. When testing under this option, the engine compartment cover must be closed.

(iv) Use a road-speed modulated fan system with a minimum air flow nozzle discharge area that is equal to or exceeds the vehicle frontal inlet area. The optimum discharge area is 1.7 m^2 (1.3 m × 1.3 m), however, other sizes can be used. The discharge nozzle should be placed nominally within the range of (60 to 90) cm from the front of the vehicle and 0 to 16 cm from the floor of the test cell. When testing under this option, the engine compartment cover must be closed.

(A) Air flow volumes must be proportional to vehicle speed. With the above optimum discharge size, the fan volume would vary from 0 cubic feet/minute (cfm) at 0 mph to approximately 95,000 cfm at 60 mph. If this fan is also the only source of cell air circulation or if fan operational mechanics make the 0 mph air flow requirement impractical, air flow of 2 mph or less will be allowed at 0 mph vehicle speed.

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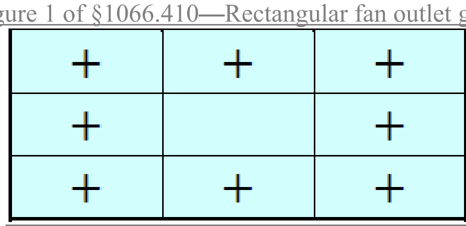
(B) The fan air flow velocity vector perpendicular to the axial flow velocity vector shall be less than 10 % of the mean velocity measured at fan speeds corresponding to vehicle speeds of 20 and 40 mph.

(C) The uniformity of fan axial flow tolerance is 20 % of the fan speed corresponding to vehicle speeds of 20 and 40 mph. Measure the fan axial air flow velocity two feet from the nozzle outlet at each point of the discharge area grid.

(1) For fans with rectangular outlets, divide the fan outlet into 9 equal sections (dividing both the horizontal and vertical sides of the fan outlet into 3 equal parts) as described in Figure 1 of §1066.410. As denoted by the "+" in the Figure, measure flow from the center of each section; however do not measure the flow from the center section.

Figure 1 of §1066.410—Rectangular fan outlet grid.



(2) For fans with circular outlets, divide the fan outlet into 8 equal sections (divide using vertical, horizontal, and 45° lines) as described in Figure 2 of §1066.410. As denoted by the "+" in the Figure, measure flow on the radial center line of each arc (at 22.5°) at a radius of two thirds of the total.

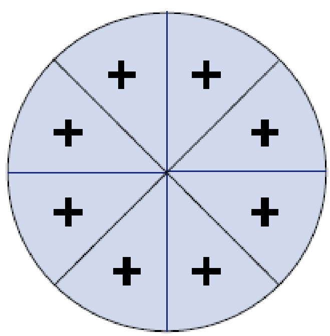


Figure 2 of §1066.410—Circular fan outlet grid.

(D) The instrument used to verify the air velocity must have an accuracy of 2 % of the measured air flow speed.

Table 1 of §1066.410–Test cell vehicle cooling fan requirements.

Test cycle	Allowable cooling fan configurations
FTP and LA-92	1066.410(b)(1)(i), 1066.410(b)(1)(iii)

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US06	1066.410(b)(1)(ii), 1066.410(b)(1)(iii)
SC03 and AC17	1066.410(b)(1)(iv)
HFET	1066.410(b)(1)(i), 1066.410(b)(1)(iii)

(2) For vehicles above 14,000 pounds GVWR, use a road-speed modulated fan system that achieves a linear speed of cooling air at the blower outlet that is within ±3.0 mph (±1.3 m/s) of the corresponding roll speed when vehicle speeds are between 5 and 30 mph (2.2 to 13.4 m/s), and within ±10 mph (±4.5 m/s) of the corresponding roll speed at higher vehicle speeds. For vehicles with GVWR above 19,500 lbs, we recommend that the cooling fan have a minimum opening of 2.75 m^2, a minimum flow rate of 3,600 m^3/min at 50 mph, and that it maintain a minimum speed profile across the duct, in the free stream flow, of ±15 % of the target flow rate. The discharge nozzle shall be placed approximately 30 to 60 cm of the front of the vehicle to provide representative cooling. When testing under this option, the engine compartment cover must be closed.

(3) If the cooling specifications in this paragraph (b) are impractical for special vehicle designs, such as vehicles with rear-mounted engines, you may arrange for an alternative fan configuration that allows for proper simulation of vehicle cooling during in-use operation, subject to our approval.

(c) Record the vehicle's speed trace based on the time and speed data from the dynamometer. Record speed to at least the nearest 0.01 mph and time to at least the nearest 0.1 s.

(d) You may perform practice runs for operating the vehicle and the dynamometer controls to meet the driving tolerances specified in §1066.430 or adjust the emission sampling equipment. Verify that the accelerator pedal allows for enough control to closely follow the prescribed driving schedule. We recommend that you verify your ability to meet the minimum dilution factor requirements of §1066.110(b)(2)(iii)(B) during these practice runs.

(e) Inflate tires on drive wheels according to the vehicle manufacturer's specifications. The tire pressure for drive wheels must be the same for dynamometer operation and for dynamometer coastdown procedures used for determining road-load coefficients. Report these tire pressure values with the test results.

(f) Tie down or load the test vehicle as needed to provide a normal force at the tire and dynamometer roll interface to prevent wheel slip. For vehicles above 14,000 pounds GVWR, report this force with the test results.

(g) For vehicles which provide four-wheel drive or all-wheel drive operation, utilize the vehicle's normal (default) mode of operation. This may involve testing four-wheel drive or all-wheel drive on a dynamometer with a separate dynamometer roll for each drive axle. Alternatively, two drive axles may use a single roll, as described in §1066.210(d)(1). You may also test the vehicle on a single roll by deactivating the second set of drive wheels, but only if this mode of operation does not decrease emissions or energy consumption relative to normal in-use operation. We may test such vehicles in multiple-wheel or all-wheel mode on one or more rolls to confirm that the alternate dynamometer procedures did not decrease emissions.

(h) Determine test weight as follows:

(1) For vehicles at or below 14,000 pounds GVWR, determine ETW as described in §1066.810. Set dynamometer vehicle inertia, *I*, based on dynamometer type, as follows:

(i) For two-wheel drive dynamometers, set *I* = ETW.

(ii) For four-wheel drive dynamometers, set *I* = 0.985·ETW.

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(2) For vehicles above 14,000 pounds GVWR, determine the vehicle's effective mass as described in 1066.310.
(i) Warm up the dynamometer as recommended by the dynamometer manufacturer.
(j) Following the test, determine the actual driving distance by counting the number of dynamometer roll or shaft revolutions, or by integrating speed over the course of testing from a high-resolution encoder system.

§1066.420 Vehicle operation.

This section describes how to test a conventionally configured vehicle (vehicles with transmission shifters, foot pedal accelerators, etc). You may ask us to modify these procedures for vehicles that do not have these control features.

(a) Start the vehicle as follows:

(1) At the beginning of the test cycle, start the vehicle according to the procedure described in the owners manual. In the case of hybrid vehicles, this would generally involve activating vehicle systems such that the engine will start when the vehicle's control algorithms determine that the engine should provide power instead of or in addition to power from the rechargeable energy storage system (RESS). Unless we specify otherwise, engine starting throughout this part generally refers to this step of activating the system on hybrid vehicles, whether or not that causes the engine to start running.

(2) Place the transmission in gear as described by the test cycle in the standard-setting part. During idle operation, you may apply the brakes if necessary to keep the drive wheels from turning.

(b) If the vehicle does not start after your recommended maximum cranking time, wait and restart cranking according to your recommended practice. If you don't recommend such a cranking procedure, stop cranking after 10 seconds, wait for 10 seconds, then start cranking again for up to 10 seconds. You may repeat this for up to three start attempts. If the vehicle does not start after three attempts, you must determine and record the reason for failure to start. Shut off sampling systems and either turn the CVS off or disconnect the exhaust tube from the tailpipe during the diagnostic period to prevent flow through the exhaust system. Reschedule the vehicle for testing. This may require performing vehicle preparation and preconditioning if the testing needs to be rerun from a cold start. If failure to start occurs during a hot start test, you may reschedule the hot start test without repeating the cold start test, as long as you bring the vehicle to a hot start condition before starting the hot start test.

(c) Repeat the recommended starting procedure if the engine has a false start (i.e., an incomplete start).

(d) Take the following steps if the engine stalls:

(1) If the engine stalls during an idle period, restart the engine immediately and continue the test. If you cannot restart the engine soon enough to allow the vehicle to follow the next acceleration, stop the driving schedule indicator and reactivate it when the vehicle restarts.

(2) Void the test if the vehicle stalls during vehicle operation. If this happens, remove the vehicle from the dynamometer, take corrective action, and reschedule the vehicle for testing. Record the reason for the malfunction (if determined) and any corrective action. See the standard-setting part for instructions about reporting these malfunctions.

(e) Operate vehicles during testing as follows:

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(1) Where we do not give specific instructions, operate the vehicle according to the recommendations in the owners manual, unless those recommendations are unrepresentative of what may reasonably be expected for in-use operation.
(2) If vehicles have features that preclude dynamometer testing, you may modify these features as necessary to allow testing, consistent with good engineering judgment, as long as it does not affect your ability to show that your vehicles comply with standards. Send us written notification describing these changes along with supporting rationale.
(3) Operate vehicles during idle as follows:
(i) For vehicles with automatic transmission, operate at idle with the transmission in "Drive" with the wheels braked, except that you may shift to "Neutral" for the first idle period and for any idle period longer than one minute. If you put the vehicle in "Neutral" during an idle, you must shift the vehicle into "Drive" with the wheels braked at least 5 seconds before the end of the idle period. Note that this does not preclude vehicle designs involving engine operation with stop-start functions where the engine stops when the brake is applied below a certain threshold speed and restarts upon release of the brake.
(ii) For vehicles with manual transmission, operate at idle with the transmission in gear with the clutch disengaged, except that you may shift to "Neutral" with the clutch engaged for the first idle period and for any idle period longer than one minute. If you put the vehicle in "Neutral" during idle, you must shift to first gear with the clutch disengaged at least 5 seconds before the end of the idle period. Note that this does not preclude vehicle designs involving engine operation with stop-start functions where the engine stops when the clutch is disengaged below a certain threshold speed and restarts upon reengagement of the clutch.
(4) Use the appropriate accelerator pedal to achieve the speed versus time relationship prescribed by the driving schedule. Avoid smoothing speed variations and excessive accelerator pedal perturbations.
(5) Operate the vehicle smoothly, following representative shift speeds and procedures. For manual transmissions, the operator shall release the accelerator pedal during each shift and accomplish the shift with minimum time. If the vehicle cannot accelerate at the specified rate, operate it at maximum available power until the vehicle speed reaches the value prescribed for that time in the driving schedule.
(6) Decelerate as follows:
(i) For vehicles with automatic transmission, use the brakes or accelerator pedal as necessary, without manually changing gears, to maintain the desired speed.
(ii) For vehicles with manual transmission, shift gears in a way that represents reasonable shift patterns for in-use operation, considering vehicle speed, engine speed, and any other relevant variables. Disengage the clutch when the speed drops below 15 mph, when engine roughness is evident, or when good engineering judgment indicates the engine is likely to stall. Manufacturers may recommend shift guidance in the owners manual that differs from the shift schedule during testing as long as both shift schedules are included in the application for certification. In this case, we may use the shift schedule based on the shift pattern described in the owners manual.

§1066.425 Test preparation.

(a) Follow the procedures for PM sample preconditioning and tare weighing as described in 40 CFR 1065.590 if you need to measure PM emissions.

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(b) For vehicles above 14,000 pounds GVWR with compression-ignition engines, verify the amount of nonmethane hydrocarbon contamination as described in 40 CFR 1065.520(g).
(c) Unless the standard-setting part specifies different tolerances, verify at some point before the test that ambient conditions are within the tolerances specified in this paragraph (c). For purposes of this paragraph (c), “before the test” means any time from a point just prior to engine starting (excluding engine restarts) to the point at which emission sampling begins.
(1) Ambient temperature must be (20 to 30) °C. See §1066.430(j) for circumstances under which ambient temperatures must remain within this range during the test.
(2) Dilution air conditions must meet the specifications in §1066.110(b)(2). We recommend verifying dilution air conditions just before starting each test interval.
(d) Control test cell ambient air humidity as follows:
(1) For vehicles at or below 14,000 pounds GVWR, follow the humidity requirements in Table 1 of this section, unless the standard-setting part specifies otherwise. When complying with humidity requirements in the table, where no tolerance is specified, use good engineering judgment to maintain the humidity level near the specified value within the limitations of your test facility.
(2) For vehicles above 14,000 pounds GVWR, you may test vehicles at any humidity.

Table 1 of §1066.425–Test cell humidity requirements.

Test cycle	Humidity requirement (grains H_2O/lb of dry air)	Tolerance (grains H_2O/lb of dry air)
AC17	69	± 5 average, ± 10 instantaneous
FTP[1] and LA-92	50	
HFET	50	
SC03	100	± 5
US06	50	

[1]FTP humidity requirement does not apply for cold (-7°C), intermediate (10 °C), and hot (35 °C) temperature testing.

(e) You may perform a final calibration of proportional-flow control systems, which may include performing practice runs.
(f) You may perform the following procedure to precondition sampling systems:
(1) Operate the vehicle over the test cycle.
(2) Operate any dilution systems at their expected flow rates. Prevent aqueous condensation in the dilution systems as described in 40 CFR 1065.140(c)(6), taking into account allowances given in §1066.110(b)(2)(iv).
(3) Operate any PM sampling systems at their expected flow rates.
(4) Sample PM using any sample media. You may change sample media during preconditioning. You must discard preconditioning samples without weighing them.
(5) You may purge any gaseous sampling systems during preconditioning.
(6) You may conduct calibrations or verifications on any idle equipment or analyzers during preconditioning.
(g) Take the following steps before emission sampling begins:

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(1) For batch sampling, connect clean storage media, such as evacuated bags or tare-weighed filters.
(2) Start all measurement instruments according to the instrument manufacturer's instructions and using good engineering judgment.
(3) Start dilution systems, sample pumps, and the data-collection system.
(4) Pre-heat or pre-cool heat exchangers in the sampling system to within their operating temperature tolerances for a test.
(5) Allow heated or cooled components such as sample lines, filters, chillers, and pumps to stabilize at their operating temperatures.
(6) Adjust the sample flow rates to desired levels using bypass flow, if desired.
(7) Zero or re-zero any electronic integrating devices before the start of any test interval.
(8) Select gas analyzer ranges. You may not switch the gain of an analyzer's analog operational amplifier(s) during a test. However, you may switch (automatically or manually) gas analyzer ranges during a test if such switching changes only the range over which the digital resolution of the instrument is applied.
(9) Zero and span all continuous gas analyzers using gases that meet the specifications of 40 CFR 1065.750. For FID analyzers, you may account for the carbon number of your span gas either during the calibration process or when calculating your final emission value. For example, if you use a C_3H_8 span gas of concentration 200 ppm (µmol/mol), you may span the FID to respond with a value of 600 ppm (µmol/mol) of carbon or 200 ppm of propane. However, if your FID response is equivalent to propane, include a factor of three to make the final calculated hydrocarbon mass consistent with a molar mass of 13.875389. When utilizing an NMC-FID, span the FID analyzer consistent with the determination of their respective response factors, *RF*, and penetration fractions, *PF*, according to 40 CFR 1065.365.
(10) We recommend that you verify gas analyzer responses after zeroing and spanning by sampling a calibration gas that has a concentration near one-half of the span gas concentration. Based on the results and good engineering judgment, you may decide whether or not to re-zero, re-span, or re-calibrate a gas analyzer before starting a test.
(11) If you correct for dilution air background concentrations of associated engine exhaust constituents, start sampling and recording background concentrations at the same time you start sampling exhaust gases.
(12) Turn on cooling fans immediately before starting the test.
(h) Proceed with the test sequence described in §1066.430.

§1066.430 Performing emission tests.
(a) See the standard-setting part for drive schedules. These are defined by a smooth trace drawn through the specified speed vs. time sequence.
(b) The driver must attempt to follow the target schedule as closely as possible, consistent with the specifications in paragraph (b) of this section. Instantaneous speeds must stay within the following tolerances:
(1) The upper limit is 2.0 mph higher than the highest point on the trace within 1.0 s of the given point in time.
(2) The lower limit is 2.0 mph lower than the lowest point on the trace within 1.0 s of the given time.
(3) The same limits apply for vehicle preconditioning and warm-up, except that the upper and lower limits for speed values are ±4.0 mph.

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Deleted: (f) Verify the amount of nonmethane hydrocarbon (or equivalent) contamination in the exhaust and background HC sampling systems within 8 hours before the start of the first test drive cycle for each individual vehicle tested as described in 40 CFR 1065.520(g).¶
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§1066.425 Engine starting and restarting.¶
(a) Start the vehicle's engine as follows:¶
(1) At the beginning of the test cycle, start the engine according to the procedure you describe in your owners manual. In the case of hybrid vehicles, this would generally involve activating vehicle systems such that the engine will start when the vehicle's control algorithms determine that the engine should provide power instead of or in addition to power from the rechargeable energy storage system (RESS). Unless we specify otherwise, engine starting throughout this part generally refers to this step of activating the system on hybrid vehicles, whether or not that causes the engine to start running.¶
(2) Place the transmission in gear as described by the test cycle in the standard-setting part. During idle operation, you may apply the brakes if necessary to keep the drive wheels from turning.¶
(b) If the vehicle does not start after your recommended maximum cranking time, wait and restart cranking according to your recommended practice. If you don't recommend such a cranking procedure, stop cranking after 10 seconds, wait for 10 seconds, then start cranking gain for up to 10 seconds. You may repeat this for up to three ... [1]
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(4) Void the test if you do not maintain speed values as specified in this paragraph (b). Speed variations (such as may occur during gear changes or braking spikes) may occur as follows, provided that such variations are clearly documented, including the time and speed values and the reason for the deviation:
(i) Speed variations greater than the specified limits are acceptable for up to 2.0 seconds on any occasion.
(ii) For vehicles that are not able to maintain acceleration as specified in §1066.420(e)(5), do not count the insufficient acceleration as being outside the specified limits.
(5) We may approve an alternate test cycle and cycle-validation criteria for vehicles that do not have enough power to follow the specified driving trace. The alternate driving specifications must be based on making best efforts to maintain acceleration and speed to follow the specified test cycle. We must approve these alternate driving specifications before you perform this testing.
(c) Figure 1 and Figure 2 of this section show the range of acceptable speed tolerances for typical points during testing. Figure 1 of this section is typical of portions of the speed curve that are increasing or decreasing throughout the 2-second time interval. Figure 2 of this section is typical of portions of the speed curve that include a maximum or minimum value.

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Figure 1 of §1066.430—Example of the allowable ranges for the driver's trace.

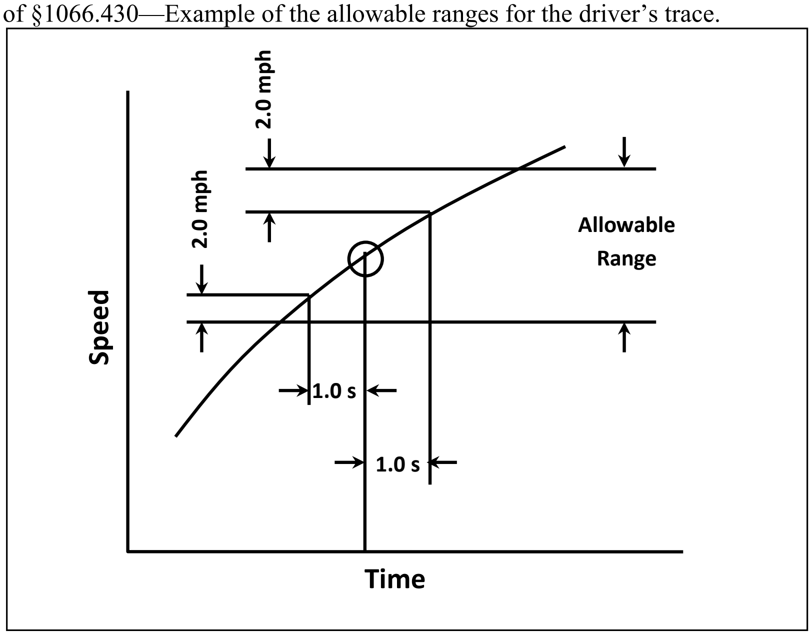
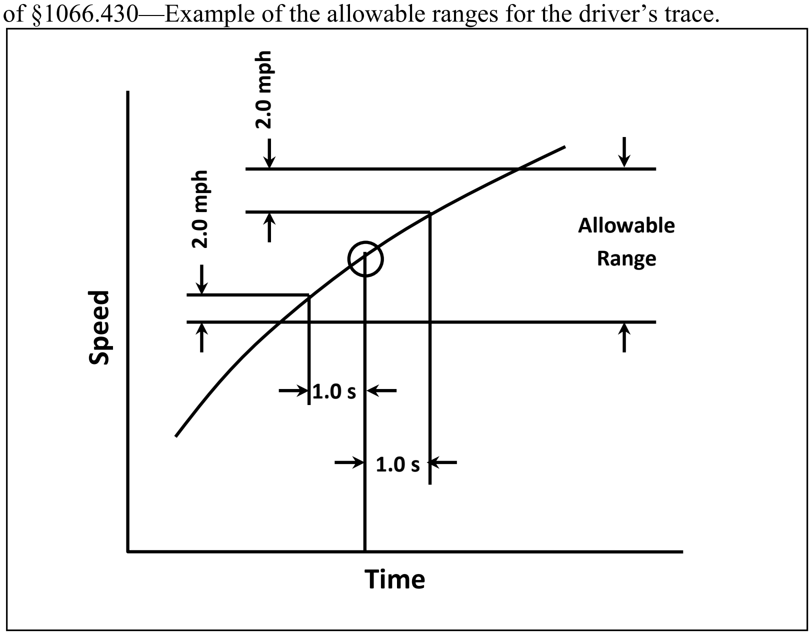


Figure 2 of §1066.430—Example of the allowable ranges for the driver's trace.



(d) Start testing as follows:
(1) If a vehicle is already running and warmed up, and starting is not part of the test cycle, operate the vehicle as follows:
(i) For transient test cycles, control vehicle speeds to follow a drive schedule consisting of a series of idles, accelerations, cruises, and decelerations.
(ii) For cruise test cycles, control the vehicle operation to match the speed of the first interval of the test cycle. Follow the instructions in the standard-setting part to determine how long to stabilize the vehicle during each interval, how long to sample emissions at each interval, and how to transition between intervals.
(2) If engine starting is part of the test cycle, initiate data logging, sampling of exhaust gases, and integrating measured values before starting the engine. Initiate the driver's trace when the engine starts.
(e) Perform the following at the end of each test interval, except as specified in subpart I of this part:
(i) Shut down the vehicle if it is part of the test cycle or if testing is complete.
(ii) Continue to operate all sampling and dilution systems to allow the response times to elapse. Then stop all sampling and recording, including background sampling. Finally, stop any integrating devices and indicate the end of the duty cycle in the recorded data.
(f) If testing involves engine shutdown followed by another test interval, start a timer for the vehicle soak when the engine shuts down. Turn off cooling fans, close the vehicle hood (if applicable), and turn off the CVS or disconnect the exhaust tube from the tailpipe(s) of the vehicle unless otherwise instructed in the standard-setting part. If testing is complete, disconnect the exhaust tube from the vehicle tailpipe(s) and drive the vehicle from dynamometer.
(g) Take the following steps after emission sampling is complete:
(1) For any proportional batch sample, such as a bag sample or PM sample, verify that proportional sampling was maintained according to 40 CFR 1065.545. Void any samples that did not maintain proportional sampling according to those specifications.
(2) Place any used PM samples into covered or sealed containers and return them to the PM-stabilization environment. Follow the PM sample post-conditioning and total weighing procedures in 40 CFR 1065.595.
(3) As soon as practical after the interval or test cycle is complete, or optionally during the soak period if practical, perform the following:
(i) Begin drift check for all continuous gas analyzers as described in paragraph (g)(6) of this section and zero and span all batch gas analyzers as soon as practical prior to any batch sample analysis. You may perform this batch analyzer zero and span prior to the end of the test cycle or interval.
(ii) Analyze any conventional gaseous batch samples (HC, CO, NO_x, and CO_2) no later than 30 minutes after an interval or test cycle is complete, or during the soak period if practical. Analyze background samples no later than 60 minutes after the test cycle is complete.
(iii) Analyze nonconventional gaseous batch samples (including background), such as NMHCE, N_2O, or NMOG sampling with ethanol, as soon as practicable using good engineering judgment.
(4) Range validation. If an analyzer operated above 100 % of its range at any time during the test, perform the following steps:

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(i) For batch sampling, re-analyze the sample using the lowest analyzer range that results in a maximum instrument response below 100 %. Report the result from the lowest range from which the analyzer operates below 100 % of its range.
(ii) For continuous sampling, repeat the entire test using the next higher analyzer range. If the analyzer again operates above 100 % of its range, repeat the test using the next higher range. Continue to repeat the test until the analyzer consistently operates at less than 100 % of its range.
(5) After quantifying exhaust gases, verify drift as follows:
(i) For batch and continuous gas analyzers, record the mean analyzer value after stabilizing a zero gas to the analyzer. Stabilization may include time to purge the analyzer of any sample gas, plus any additional time to account for analyzer response.
(ii) Record the mean analyzer value after stabilizing the span gas to the analyzer. Stabilization may include time to purge the analyzer of any sample gas, plus any additional time to account for analyzer response.
(iii) Use these data to validate that analyzer drift does not exceed 2.0 % of the analyzer full scale.
(h) [Reserved]
(i) Measure and record ambient pressure. Measure and record ambient temperature continuously to verify that it remains within the temperature range specified in §1066.425(c)(1) throughout the test. Also measure humidity, if required, such as for correcting NO_x emissions, or meeting the requirements of §1066.425(d).
(j) For vehicles at or below 14,000 pounds GVWR, determine overall driver accuracy as follows:
(1) Compare the following drive cycle metrics, based on measured vehicle speeds, to a reference value based on the target cycle that would have been generated by driving exactly to the target trace as described in SAE J2951 (incorporated by reference in §1066.1010).
(i) Determine the Energy Economy Rating as described in Section 5.4 of SAE J2951.
(ii) Determine the Absolute Speed Change Rating as described in Section 6.1.2 of SAE J2951.
(iii) Calculate the Inertia Work Rating, *IR*, using the both the sums of the incremental driven and the target inertia work as described in Eq. 1066.430-1.

$$IR = \left(\frac{\sum_{i=1}^{n} F_{\mathrm{ID}_i} \cdot D_{\mathrm{D}_i} - \sum_{j=1}^{m} F_{\mathrm{IT}_j} \cdot D_{\mathrm{T}_j}}{\sum_{j=1}^{m} F_{\mathrm{IT}_j} \cdot D_{\mathrm{T}_j}} \right) \cdot 100$$

Eq. 1066.430-1

Where:
F_{ID_i} = the driven inertial force over an interval *i*, as described by Equation 18 of SAE J2951.
F_{ID_j} = the target inertial force over an interval *j*, as described by Equation 19 of SAE J2951.
D_{D_i} = the incremental driven distance over an interval *i*, as described by Equation 12 of SAE J2951.
D_{D_j} = the incremental target distance over an interval *j*, as described by Equation 13 of SAE J2951.
(2) The standard-setting part may require you to provide to us 10 Hz data to characterize both target and actual values for cycle energy. Calculate target values based on the vehicles speeds from the specified test cycle.

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(1) Air-cooled engines.¶
(2) Engines equipped with emission control devices that sense and respond to ambient temperature.¶
(3) Any other engine for which good engineering judgment indicates that this is necessary to remain consistent with 40 CFR 1065.10(c)(1).
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(3) Determine the inertial work ratio as described in Section 7.2.3 of SAE J2951.

Subpart F—Hybrids and Electric Vehicles

§1066.501 Overview.

For HEV, PHEV, and pure electric vehicle (EV), use the following procedures:

(a) Correct the results for Net Energy Change of the RESS as follows:

(1) For vehicles at or below 14,000 pounds GVWR, follow SAE J1711 (incorporated by reference in §1066.1010) except as noted in this paragraph (a). Use ±1 % of reading or ±0.3 % of full scale, whichever is greater, in place of the current measurement accuracy in Section 4.2a of SAE J1711.

(2) For vehicles above 14,000 pounds GVWR, follow SAE J2711 (incorporated by reference in §1066.1010) for requirements related to charge-sustaining operation.

(3) For pure EVs, irrespective of GVWR, follow SAE J1634 (incorporated by reference in §1066.1010).

(b) This paragraph (b) applies for vehicles that include an engine-powered generator or other auxiliary power unit that provides motive power. For example, this would include a vehicle that has a small gasoline engine that generates electricity to charge batteries. Unless we approve otherwise, measure emissions for all test cycles when such an engine is operating. For each test cycle for which emissions are not measured, you must validate that such engines are not operating at any time during the test cycle.

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Subpart G—Calculations

§1066.601 Overview.

(a) The calculations described in this subpart apply as specified elsewhere in this part. This subpart describes how to–

(1) Use the signals recorded before, during, and after an emission test to calculate distance-specific emissions of each regulated pollutant.

(2) Perform calculations for calibrations and performance checks.

(3) Determine statistical values.

(b) You may use data from multiple systems to calculate test results for a single emission test, consistent with good engineering judgment. You may also make multiple measurements from a single batch sample, such as multiple weighing of a PM filter or multiple readings from a bag sample. You may not use test results from multiple emission tests to report emissions. We allow weighted means where appropriate. You may discard statistical outliers, but you must report all results.

§1066.610 Mass-based and molar-based exhaust emission calculations.

(a) Calculate your total mass of emissions over a test cycle as specified in paragraph (c) of this section or in 40 CFR part 1065, subpart G, as applicable.

(b) For composite emission calculations over multiple test intervals and corresponding weighting factors, see the standard-setting part.

(c) To calculate total mass emissions, multiply a concentration by its respective flow and density as specified in Eq. 1066.610-1. Before calculating mass emissions as specified in paragraph (d) and (e) of this section, perform the following sequence of preliminary calculations to correct recorded concentration measurements:

(1) For vehicles above 14,000 pounds GVWR, correct all THC and CH_4 concentrations for initial contamination as described in 40 CFR 1065.660(a), including continuous readings, sample bags readings, and dilution air background readings. This correction is optional for vehicles at or below 14,000 pounds GVWR.

(2) Correct all concentrations measured on a "dry" basis to a "wet" basis, including dilution air background concentrations.

(3) Calculate all NMHC and CH_4 concentrations, including dilution air background concentrations, as described in 40 CFR 1065.660.

(4) For vehicles at or below 14,000 pounds GVWR, calculate HC concentrations, including dilution air background concentrations, as described in this section and §1066.665 for NMOG. For emission testing of vehicles above 14,000 pounds GVWR, with fuels that contain 25% or more oxygenated compounds by volume, calculate HC concentrations, including dilution air background concentrations, as described in 40 CFR part 1065, subpart I, for THCE and NMHCE.

(5) Correct all NO_x emission values for test cell ambient air humidity as described in §1066.630.

(6) Correct all gaseous concentrations for dilution air background as described in §1066.620.

(7) Correct all PM filter masses for sample media buoyancy as described in 40 CFR 1065.690.

(d) Calculate the emission mass of each gaseous pollutant using the following equation:

$$m_{[\text{emission}]} = V_{\text{mix}} \cdot \rho_{[\text{emission}]} \cdot x_{[\text{emission}]} \cdot c$$

Eq. 1066.610-1

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(1) Concentration corrections. Perform the following sequence of preliminary calculations on recorded concentrations before calculating mass emissions as specified in paragraph (d) of this section:

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Where:
$m_{[emission]}$ = emission mass over the test interval.
V_{mix} = total dilute exhaust volume over the test interval at standard reference conditions, corrected for any volume removed for emission sampling and the addition of secondary dilution air (if applicable).
$\rho_{[emission]}$ = density of the appropriate chemical species as given in §1066.1005(f).
$x_{[emission]}$ = measured emission concentration in the sample, after dry-to-wet and background corrections.
$c = 10^{-2}$ for emission concentrations % and 10^{-6} for emission concentrations in ppm.

Example:
V_{mix} = 170.877 m^3 (from paragraph (f) of this section)
ρ_{NOx} = 1913 g/m^3
x_{NOx} = 0.9721 ppm
$c = 10^{-6}$

$$m_{\mathrm{NOx}} = 170.877 \cdot 1913 \cdot 0.9721 \cdot 10^{-6} = 0.3177\ \mathrm{g}$$

(e) The calculation of PM is dependent on how many PM filters are used (for example as described in §1066.822(b)), as follows:
(1) Except as specified in pargraphs (e)(2) and (3) of this section, calculate m_{PM} using the following equation:

$$m_{\mathrm{PM}} = \left(\frac{V_{\mathrm{mix}}}{V_{\mathrm{PMstd}} - V_{\mathrm{sdastd}}}\right) \cdot \left(m_{\mathrm{PMfil}} - m_{\mathrm{PMbkgnd}}\right)$$

Eq. 1066.610-2

Where:
m_{PM} = mass of particulate matter emissions over the test interval.
V_{mix} = total dilute exhaust volume over the test interval at standard reference conditions, corrected for any volume removed for emissions sampling and the addition of secondary dilution air (if applicable).
V_{sdastd} = total volume of secondary dilution air flow sampled through the filter over the test phase at standard temperature and pressure.
m_{PMfil} = mass of particulate matter emissions on the filter over the test interval.
$m_{PMbkgnd}$ = mass of particulate matter on the background filter.

Example:
V_{mix} = 170.877 m^3 (from paragraph (f) of this section)
V_{PMstd} = 0.9246 m^3 (from paragraph (f) of this section)
V_{sdastd} = 0.527 m^3 (from paragraph (f) of this section)
m_{PMfil} = 0.0000045 g
$m_{PMbkgnd}$ = 0.0000014 g

$$m_{\mathrm{PM}} = \left(\frac{170.877}{0.9246 - 0.527}\right) \cdot \left(0.0000045 - 0.0000014\right) = 0.00133\ \mathrm{g}$$

(2) If you sample PM onto a single filter as described in §1066.820(b)(4), calculate m_{PM} using the following equation:

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$$m_{PM} = \left(\frac{V_{mix}}{\frac{(V_{ct\text{-}PMstd} - V_{ct\text{-}sdastd})}{0.43} + (V_{s\text{-}PMstd} - V_{s\text{-}sdastd}) + \frac{(V_{ht\text{-}PMstd} - V_{ht\text{-}sdastd})}{0.57}} \right) \cdot (m_{PMfil} - m_{PMbkgnd})$$

Eq. 1066.610-3

Where:

m_{PM} = mass of particulate matter emissions over the entire FTP as sampled according to §1066.820(b)(1).

V_{mix} = total dilute exhaust volume over the test interval at standard reference conditions, corrected for any volume removed for emissions sampling and the addition of secondary dilution air (if applicable).

$V_{[interval]\text{-}PMstd}$ = total volume of dilute exhaust sampled through the filter over the test interval (ct = cold transient, s = stabilized, ht = hot transient) at standard reference conditions.

$V_{[interval]\text{-}sdastd}$ = total volume of secondary dilution air sampled through the filter over the test interval (ct = cold transient, s = stabilized, ht = hot transient) at standard reference conditions.

m_{PMfil} = mass of particulate matter emissions on the filter over the test interval.

$m_{PMbkgnd}$ = mass of particulate matter on the background filter.

Example:

V_{mix} = 633.69 m^3

$V_{ct\text{-}PMstd}$ = 0.9248 m^3

$V_{ct\text{-}sdastd}$ = 0.527 m^3

$V_{s\text{-}PMstd}$ = 1.9676 m^3

$V_{s\text{-}sdastd}$ = 1.1212 m^3

$V_{ht\text{-}PMstd}$ = 1.1215 m^3

$V_{ht\text{-}sdastd}$ = 0.639 m^3

m_{PMfil} = 0.0000106 g

$m_{PMbkgnd}$ = 0.0000014 g

$$m_{PM} = \left(\frac{633.69}{\frac{(0.9248 - 0.527)}{0.43} + (1.9676 - 1.1212) + \frac{(1.1215 - 0.639)}{0.57}} \right) \cdot (0.0000106 - 0.0000014)$$

m_{PM} = 0.00223 g

(3) If you sample PM onto a single filter as described in §1066.820(b)(5), calculate m_{PM} using the following equation:

$$m_{PM} = \left(\frac{V_{mix}}{\frac{(V_{ct\text{-}PMstd} - V_{ct\text{-}sdastd}) + (V_{cs\text{-}PMstd} - V_{cs\text{-}sdastd})}{0.43} + \frac{(V_{ht\text{-}PMstd} - V_{ht\text{-}sdastd}) + (V_{hs\text{-}PMstd} - V_{hs\text{-}sdastd})}{0.57}} \right) \cdot (m_{PMfil} - m_{PMbkgnd})$$

Eq. 1066.610-4

Where:

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m_{PM} = mass of particulate matter emissions over the entire FTP as sampled according to §1066.820(b)(2).
V_{mix} = total dilute exhaust volume over the test interval at standard reference conditions, corrected for any volume removed for emissions sampling and the addition of secondary dilution air (if applicable).
$V_{[interval]\text{-}PMstd}$ = total volume of dilute exhaust sampled through the filter over the test interval (ct = cold transient, cs = cold stabilized, ht = hot transient, hs = hot stabilized) at standard reference conditions.
$V_{[interval]\text{-}sdastd}$ = total volume of secondary dilution air sampled through the filter over the test interval (ct = cold transient, cs = cold stabilized, ht = hot transient, hs = hot stabilized) at standard reference conditions.
m_{PMfil} = mass of particulate matter emissions on the filter over the test interval.
$m_{PMbkgnd}$ = mass of particulate matter on the background filter.

Example:
$V_{mix} = 972.12\ \text{m}^3$
$V_{ct\text{-}PMstd} = 0.9236\ \text{m}^3$
$V_{ct\text{-}sdastd} = 0.529\ \text{m}^3$
$V_{cs\text{-}PMstd} = 1.9666\ \text{m}^3$
$V_{cs\text{-}sdastd} = 1.1209\ \text{m}^3$
$V_{ht\text{-}PMstd} = 1.1218\ \text{m}^3$
$V_{ht\text{-}sdastd} = 0.641\ \text{m}^3$
$V_{hs\text{-}PMstd} = 1.9674\ \text{m}^3$
$V_{hs\text{-}sdastd} = 1.1213\ \text{m}^3$
$m_{PMfil} = 0.0000229\ \text{g}$
$m_{PMbkgnd} = 0.0000014\ \text{g}$

$$m_{PM} = \left(\frac{972.12}{\frac{(0.9236-0.529)+(1.9666-1.1209)}{0.43} + \frac{(1.1218-0.641)+(1.9674-1.1213)}{0.57}} \right) \cdot (0.0000229-0.0000014)$$

$m_{PM} = 0.00155\ \text{g}$

(f) This paragraph (f) describes how to correct flow and flow rates to standard reference conditions and provides an example of how to determine V_{mix} based on CVS total flow and the removal of sample flow from the dilute exhaust gas.
(1)Correct flow and flow rates to standard reference conditions as needed using the following equation:

$$V_{[flow]std} = \frac{V_{[flow]act} \cdot p_{in} \cdot T_{std}}{p_{std} \cdot T_{in}}$$

Eq. 1066.610-5

Where:
$V_{[flow]std}$ = total volume of flow at the flow meter at standard reference conditions.
$V_{[flow]act}$ = total volume of flow at the flow meter at test conditions.
p_{in} = flow meter inlet absolute static pressure. Measure absolute static pressure directly or calculate it as the sum of atmospheric pressure plus a differential pressure that is referenced to atmospheric pressure.

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T_{std} = standard temperature.
p_{std} = standard pressure.
T_{in} = average temperature of the dilute exhaust sample at the flow meter inlet.

Example:
V_{PMact} = 1.07 m^3
p_{in} = 101.7 kPa
T_{std} = 293.15 K
p_{std} = 101.325 kPa
T_{in} = 340.5 K

$$V_{\mathrm{PMstd}} = \frac{1.07 \cdot 101.7 \cdot 293.15}{101.325 \cdot 340.5} = 0.9246\ \mathrm{m}^3$$

(2) The following example provides a determination of V_{mix} based on CVS total flow and the removal of sample flow from one dilute exhaust gas analyzer and one PM sampler that is utilizing secondary dilution. Note that your V_{mix} determination may vary from Eq. 1066.610-6 based on the number of flows that are removed from your dilute exhaust gas and whether your PM sampler is using secondary dilution. For this example, V_{mix} is governed by the following equation:

$$V_{\mathrm{mix}} = V_{\mathrm{CVSstd}} + V_{\mathrm{gasstd}} + V_{\mathrm{PMstd}} - V_{\mathrm{sdastd}}$$

Eq. 1066.610-6

Where:
V_{CVSstd} = total dilute exhaust volume over the test interval at the flow meter at standard reference conditions.
V_{gasstd} = total volume of sample flow through the gaseous emission bench over the test interval at standard reference conditions.
V_{PMstd} = total volume of dilute exhaust sampled through the filter over the test interval at standard reference conditions.
V_{sdastd} = total volume of secondary dilution air flow sampled through the filter over the test interval at standard reference conditions.

Example:
Using Eq. 1066.610-5
V_{CVSstd} = 170.492 m^3, where V_{CVSact} = 170.72 m^3, p_{in} = 101.7 kPa, and T_{in} = 294.7 K
Using Eq. 1066.610-5
V_{gasstd} = 0.0291 m^3, where V_{gasact} = 0.0337 m^3, p_{in} = 101.7 kPa, and T_{in} = 340.5 K
Using Eq. 1066.610-5
V_{PMstd} = 0.9246 m^3, where V_{PMact} = 1.07 m^3, p_{in} = 101.7 kPa, and T_{in} = 340.5 K
Using Eq. 1066.610-5
V_{sdastd} = 0.527 m^3, where V_{sdaact} = 0.531 m^3, p_{in} = 101.7 kPa, and T_{in} = 296.3 K
V_{mix} = 170.445 + 0.0291 + 0.9246 – 0.527 = 170.877 m^3

§1066.620 Dilution air background correction.
(a) Correct the emissions in a gaseous sample for background using the following equation:

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$$x_{[\text{emission}]} = x_{[\text{emission}]\text{dexh}} - x_{[\text{emission}]\text{bkgnd}} \cdot \left(1 - \left(\frac{1}{DF}\right)\right)$$

Eq. 1066.620-1

Where:

$x_{[\text{emission}]\text{dexh}}$ = measured emission concentration in dilute exhaust (after dry-to-wet correction for dry measurements).

$x_{[\text{emission}]\text{bkgnd}}$ = measured emission concentration in the dilution air (after dry-to-wet correction for dry measurements).

DF = dilution factor determined in paragraph (b) of this section.

Example:

x_{NOxdexh} = 1.08305 ppm

x_{NOxbkgnd} = 0.12456 ppm

DF = 9.14506

$$x_{\text{NOx}} = 1.08305 - 0.12456 \cdot \left(1 - \left(\frac{1}{9.14506}\right)\right) = 0.97211 \text{ ppm}$$

(b) Determine the dilution factor, *DF*, over the test interval using the following equation:

$$DF = \frac{1}{\left(1 + \frac{\alpha}{2} + 3.76 \cdot \left(1 + \frac{\alpha}{4} - \frac{\beta}{2}\right)\right) \cdot (x_{\text{CO2}} + x_{\text{NMHC}} + x_{\text{CH4}} + x_{\text{CO}})}$$

Eq. 1066.620-2

Where:

x_{CO2} = amount of CO_2 measured in the sample over the test interval.

x_{NMHC} = amount of C_1-equivalent NMHC measured in the sample over the test interval.

x_{CH4} = amount of CH_4 measured in the sample over the test interval.

x_{CO} = amount of CO measured in the sample over the test interval.

α = atomic hydrogen-to-carbon ratio of the test. You may measure α or use default values from Table 1 of 40 CFR 1065.655.

β = atomic oxygen-to-carbon ratio of the test fuel. You may measure β or use default values from Table 1 of 40 CFR 1065.655.

Example:

x_{CO2} = 1.456 % = 0.01456

x_{NMHC} = 0.84 ppm = 0.00000084

x_{CH4} = 0.26 ppm = 0.00000026

x_{CO} = 80.4 ppm = 0.0000804

α = 1.92

β = 0.03

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$$DF = \frac{100 \cdot \frac{1}{1 + \frac{\alpha}{2} + 3.76 \cdot \left(1 + \frac{\alpha}{4} - \frac{\beta}{2}\right)}}{x_{\text{CO2}} + x_{\text{THC}} + x_{\text{CO}}}$$

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Eq. 1066.620-2¶

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$$DF = \frac{1}{\left(1+\frac{1.92}{2}+3.76\cdot\left(1+\frac{1.92}{4}-\frac{0.03}{2}\right)\right)\cdot(0.01456+0.00000084+0.00000026+0.0000804)} = 9.14506$$

(c) Determine the dilution factor, *DF*, over the test interval for partial flow dilution sample systems that measure PM using the following equation:

$$DF = \frac{V_{\text{PMstd}}}{V_{\text{exhstd}}}$$

Eq. 1066.620-3

Where:

V_{PMstd} = total dilute exhaust volume sampled through the filter over the test interval at standard reference conditions.

V_{exhstd} = total exhaust volume sampled from the vehicle at standard reference conditions.

Example:

$V_{\text{PMstd}} = 170.9\ \text{m}^3$

$V_{\text{exhstd}} = 15.9\ \text{m}^3$

$$DF = \frac{170.9}{15.4} = 11.1$$

(d) Determine the time weighted dilution factor, DF_w, over the duty cycle using the following equation:

$$DF_{\text{w}} = \frac{\sum_{i=1}^{N} t_{\text{i}}}{\sum_{i=1}^{N} \frac{1}{DF_{\text{i}}} \cdot t_{\text{i}}}$$

Eq. 1066.620-4

Where:

N = number of test intervals.

i = test interval number

t = duration of the test interval.

DF = dilution factor over the test interval.

Example:

$N = 3$

$DF_1 = 14.80$

$t_1 = 505$ s

$DF_2 = 24.48$

$t_2 = 867$ s

$DF_3 = 17.28$

$t_3 = 505$ s

$$DF_{\text{w}} = \frac{505+867+505}{\left(\frac{1}{14.80}\cdot 505\right)+\left(\frac{1}{24.48}\cdot 867\right)+\left(\frac{1}{17.28}\cdot 505\right)} = 18.82$$

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§1066.630 NO_x intake-air humidity correction.

See the standard-setting part to determine if you may correct NO_x emissions for the effects of intake-air humidity. Correct NO_x emissions for intake-air humidity as described in this section. See §1066.610(c)(1) for the proper sequence for applying the NO_x intake-air humidity correction.

(a) For vehicles at or below 14,000 pounds GVWR, apply a correction for any reciprocating engines for the following test cycles:

(1) Calculate a humidity correction using a time-weighted mean value for ambient humidity over the test interval. Calculate absolute ambient humidity in grams H_2O vapor per kilogram of dry air using the following equation:

$$H = \frac{1000 \cdot M_{H2O} \cdot p_d \cdot RH\% \cdot 0.01}{M_{air} \cdot \left(p_{atmos} - p_d \cdot RH\% \cdot 0.01\right)}$$

Eq. 1066.630-1

Where:

M_{H2O} = molar mass of H_2O, in g/mol.

p_d = saturated vapor pressure at the ambient dry bulb temperature, in kPa.

$RH\%$ = relative humidity of ambient air, in %.

M_{air} = molar mass of air, in g/mol.

p_{atmos} = atmospheric pressure, in kPa.

Example:

M_{H2O} = 18.01528 g/mol

p_d = 2.93 kPa

$RH\%$ = 37.5 %

M_{air} = 28.96559 g/mol

p_{atmos} = 96.71 kPa

$$H = \frac{1000 \cdot 18.01528 \cdot 2.93 \cdot 37.5 \cdot 0.01}{28.96559 \cdot \left(96.71 - 2.93 \cdot 37.5 \cdot 0.01\right)} = 7.14741 \text{ g } H_2O \text{ vapor/kg dry air}$$

(2) Use the following equation to correct measured concentrations to a reference condition of 10.71 grams H_2O vapor per kilogram of dry air for the FTP, US06, LA-92, SC03, and HFET test cycles:

$$x_{NOxdexhcor} = x_{NOxdexh} \cdot \frac{H_s}{1 - 0.0329 \cdot \left(H - 10.71\right)}$$

Eq. 1066.630-2

Where:

$x_{NOxdexh}$ = measured dilute NO_x emissions.

H_s = humidity scale. Set = 1 for FTP, US06, LA-92, and HFET test cycles. Set = 0.8825 for the SC03 test cycle.

H = absolute humidity, from paragraph (a)(1) of this section.

Example:

H = 7.14741 g H2O vapor/kg dry air

$x_{NOxdexh}$ = 1.21 ppm

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$$H = \frac{M_{H2O} \cdot RH\% \cdot p_d}{M_{air} \cdot \left(p_{atmos} - p_d \cdot RH\%\right)}$$ ¶

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RH = Relative humidity of ambient air.¶
M_{air} = molar mass of air in kg/mol.¶
p_d = Saturated vapor pressure at the ambient dry bulb temperature.¶
p_B = barometric pressure.¶

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P_d = 2.93 kPa¶
P_B = 96.71 kPa¶

$$x_{\mathrm{NOxdexhcor}} = 1.21 \cdot \frac{1}{1-0.0329\cdot\left(7.14741-10.71\right)} = 1.08305 \text{ ppm}$$

(b) For vehicles above 14,000 pounds GVWR, apply correction factors as described in 40 CFR 1065.670.

§1066.640 Removed water correction.

Correct for removed water if water removal occurs upstream of a concentration measurement and downstream of a flow meter used to determine mass emissions over a test interval. Perform this correction based on the amount of water at the concentration measurement and on the amount of water at the flow meter.

§1066.650 Flow meter calibration calculations.

This section describes how to calibrate various flow meters based on mass flow rates. Calibrate your flow meter according to 40 CFR 1065.640 instead if you calculate emissions based on molar flow rates.

(a) PDP calibration calculations. Perform the following steps to calibrate a PDP flow meter:

(1) Calculate PDP volume pumped per revolution, V_{rev}, for each restrictor position from the mean values determined in §1066.140:

$$V_{\mathrm{rev}} = \frac{\bar{\dot{Q}}_{\mathrm{ref}} \cdot \bar{T}_{\mathrm{in}} \cdot p_{\mathrm{std}}}{\bar{f}_{\mathrm{nPDP}} \cdot \bar{p}_{\mathrm{in}} \cdot T_{\mathrm{std}}}$$

Eq. 1066.650-1

Where:

$\bar{\dot{Q}}_{\mathrm{ref}}$ = mean flow rate of the reference flow meter.

$\bar{T}_{\mathrm{in}}$ = mean temperature at the PDP inlet.

p_{std} = standard pressure= 101.325 kPa.

$\bar{f}_{\mathrm{nPDP}}$ = mean PDP speed.

$\bar{p}_{\mathrm{in}}$ = mean static absolute pressure at the PDP inlet.

T_{std} = standard temperature= 293.15 K.

Example:

$\bar{\dot{Q}}_{\mathrm{ref}}$ = 0.1651 m^3/s

$\bar{T}_{\mathrm{in}}$ = 299.5 K

p_{std} = 101.325 kPa

$\bar{f}_{\mathrm{nPDP}}$ = 1205.1 r/min = 20.085 r/s

$\bar{p}_{\mathrm{in}}$ = 98.290 kPa

T_{std} = 293.15 K

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¶

Deleted: (2) For the SC03 test cycle, use the following equation to correct measured concentrations to a reference condition of 10.71 of H_2O vapor per kilogram of dry air:¶

$x_{\mathrm{NOxdexhcor}} = x_{\mathrm{NOxdexh}} \cdot \frac{0.8825}{1-0.0329\cdot(H -}$

¶

Eq. 1066.630-3¶

¶

Where:¶

H = Absolute humidity in grams of H_2O vapor per kilogram of dry air according to Eq. 1066.630-2.¶

¶

Example:¶

RH = 55.9 %¶

P_d = 2.93 kPa¶ ... [19]

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$$V_{rev} = \frac{0.1651 \cdot 299.5 \cdot 101.3}{20.085 \cdot 98.290 \cdot 293.15}$$

V_{rev} = 0.00866 m^3/r

(2) Calculate a PDP slip correction factor, K_s for each restrictor position from the mean values determined in §1066.140:

$$K_s = \frac{1}{\bar{f}_{\text{nPDP}}} \cdot \sqrt{\frac{\bar{p}_{\text{out}} - \bar{p}_{\text{in}}}{\bar{p}_{\text{out}}}}$$

Eq. 1066.650-2

Where:

$\bar{f}_{\text{nPDP}}$ = mean PDP speed.

$\bar{p}_{\text{out}}$ = mean static absolute pressure at the PDP outlet.

$\bar{p}_{\text{in}}$ = mean static absolute pressure at the PDP inlet.

Example:

$\bar{f}_{\text{nPDP}}$ = 1205.1 r/min = 20.085 r/s

$\bar{p}_{\text{out}}$ = 100.103 kPa

$\bar{p}_{\text{in}}$ = 98.290 kPa

$$K_s = \frac{1}{20.085} \cdot \sqrt{\frac{100.103 - 98.290}{100.103}}$$

K_s = 0.006700 s/r

(3) Perform a least-squares regression of V_{rev}, versus PDP K_s, by calculating slope, a_1, and intercept, a_0, as described in 40 CFR 1065.602.

(4) Repeat the procedure in paragraphs (a)(1) through (3) of this section for every speed that you run your PDP.

(5) The following example illustrates a range of typical values for different PDP speeds:

Table 1 of §1066.650–
Example of PDP calibration data

$\bar{f}_{\text{nPDP}}$ (r/min)	a_1 (m^3/min)	a_0 (m^3/r)
12.6	0.841	0.056
16.5	0.831	-0.013
20.9	0.809	0.028
23.4	0.788	-0.061

(6) For each speed at which you operate the PDP, use the appropriate regression equation from this paragraph (a) to calculate flow rate during emission testing as described in §1066.652.

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(b) SSV calibration. Perform the following steps to calibrate an SSV flow meter:

(1) Calculate the Reynolds number, $Re^{\#}$, for each reference volumetric flow rate, using the throat diameter of the venturi, d_t, and the mass air flow rate of the reference flow meter, $\dot{Q}_{\text{m-ref}}$.
Assume an initial value for C_d = 0.98 to calculate $\dot{Q}_{\text{m-ref}}$.

$$Re^{\#} = \frac{66670 \cdot \dot{Q}_{\text{m-ref}}}{\pi \cdot d_t \cdot \mu}$$

Eq. 1066.650-3

Where:

μ = viscosity of air in centipoises calculated using Eq. 1066.650-4.

$$\mu = 1.458 \cdot 10^{-3} \cdot \frac{T^{\frac{3}{2}}}{T + 110.4}$$

Eq. 1066.650-4

Where:

T = the temperature at the SSV inlet in Kelvin.

If the calibration venturi is used at the tunnel inlet (free standing), then assume a value of β = 0. If the SSV is installed in the CVS tunnel, use the actual inside tunnel diameter and the throat diameter to compute β, where β is the ratio of venturi throat to inlet diameters.

(2) From the initial calibration of the venturi, establish an equation of C_d as a function of $Re^{\#}$. The following functional forms should be reviewed, but a power series, least-squares fit polynomial equation may result in the best fit. Many factors involved in the installation of SSV and the operating range of the Reynolds number can affect the functional relationship of C_d with $Re^{\#}$. Calculate C_d based on this initial equation of $Re^{\#}$. Compute a final $\dot{Q}_m$ based on this calculated C_d for both the calibration nozzle and the inline SSV.

(3)(i) Compute the percent difference in air flow between the calibration venturi and the inline SSV. If the difference in percent of point is greater than 1%, compute a new C_d and $Re^{\#}$ for the in-tunnel venturi as follows:

$$C_{\text{dnew}} = \frac{\dot{Q}_{\text{mact}}}{\dot{Q}_{\text{mtheo}}}$$

Eq. 1066.650-5

Where:

C_{dnew} = the ratio of actual air flow/theoretical air flow.

$\dot{Q}_{\text{mact}}$ = flow measured by the calibration venturi, kg/min.

$\dot{Q}_{\text{mtheo}}$ = the theoretical calculated flow based on the in-tunnel SSV conditions with C_d set equal to 1, kg/min.

$$Re^{\#}_{\text{new}} = \frac{0.8 \cdot \dot{Q}_{\text{m-ref}}}{\pi \cdot d_t \cdot \mu}$$

Eq. 1066.650-6

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$Re^{\#}_{\text{new}}$ = Reynolds number based on the calibrated venturi flow, but the in-tunnel SSV properties.

(ii) Recalculate a new curve fit of C_{dnew} for the inline venturi as a function of $Re^{\#}_{\text{new}}$ following the guidelines in paragraph (b)(1) of this section. Agreement of the fit should be within 1.0 % of point. Install the new C_{d} curve fit in the test cell flow computing device and conduct the propane injection flow verification test as described in 40 CFR 1065.341.

(c) CFV calibration. Some CFV flow meters consist of a single venturi and some consist of multiple venturis, where different combinations of venturis are used to meter different flow rates. For CFV flow meters that consist of multiple venturis, either calibrate each venturi independently to determine a separate calibration coefficient, K_{v}, for each venturi, or calibrate each combination of venturis as one venturi by determining K_{v} for the system.

(1) To determine K_{v} for a single venturi or a combination of venturis, perform the following steps:

(i) Calculate an individual K_{v} for each calibration set point for each restrictor position using the following equation:

$$K_{\text{v}} = \frac{\bar{\dot{Q}}_{\text{refstd}} \cdot \sqrt{\bar{T}_{\text{in}}}}{\bar{p}_{\text{in}}}$$

Eq. 1066.650-7

Where:

$\bar{\dot{Q}}_{\text{refstd}}$ = mean flow rate from the reference flow meter, at standard reference conditions.

$\bar{T}_{\text{in}}$ = mean temperature at the venturi inlet.

$\bar{p}_{\text{in}}$ = mean static absolute pressure at the venturi inlet.

(ii) Calculate the mean and standard deviation of all the K_{v} values (see 40 CFR 1065.602). Verify choked flow by plotting K_{v} as a function of $\bar{p}_{\text{in}}$. K_{v} will have a relatively constant value for choked flow; as vacuum pressure increases, the venturi will become unchoked and K_{v} will decrease. Paragraphs (c)(1)(iii) through (viii) of this section describe how to verify your range of choked flow.

(iii) If the standard deviation of all the K_{v} values is less than or equal to 0.3 % of the mean K_{v}, use the mean K_{v} in Eq. 1066.652-7, and use the CFV only up to the highest venturi pressure ratio, r, measured during calibration using the following equation:

$$r = 1 - \frac{\Delta p_{\text{CFV}}}{\bar{p}_{\text{in}}}$$

Eq. 1066.650-8

Where:

Δp_{CFV} = differential static pressure; venturi inlet minus venturi outlet.

(iv) If the standard deviation of all the K_{v} values exceeds 0.3 % of the mean K_{v}, omit the K_{v} value corresponding to the data point collected at the highest r measured during calibration.

(v) If the number of remaining data points is less than seven, take corrective action by checking your calibration data or repeating the calibration process. If you repeat the calibration process, we recommend checking for leaks, applying tighter tolerances to measurements and allowing

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more time for flows to stabilize.

(vi) If the number of remaining K_v values is seven or greater, recalculate the mean and standard deviation of the remaining K_v values.

(vii) If the standard deviation of the remaining K_v values is less than or equal to 0.3 % of the mean of the remaining K_v, use that mean K_v in Eq 1066.652-7, and use the CFV values only up to the highest r associated with the remaining K_v.

(viii) If the standard deviation of the remaining K_v still exceeds 0.3 % of the mean of the remaining K_v values, repeat the steps in paragraph (c)(1)(iv) through (vii) of this section.

(2) During exhaust emission tests, monitor sonic flow in the CFV by monitoring the CFV pressure ratio. Based on the calibration data selected to meet the criteria for paragraphs (c)(1)(iv) and (vii) of this section, in which K_v is constant, select the data values associated with the calibration point with the lowest absolute venturi inlet pressure to determine the r limit. Calculate r during the exhaust emission test using Eq. 1066.650-8 to demonstrate that the value of r during all emission tests is less than or equal to the r limit derived from the CFV calibration data.

§1066.652 PDP, SSV, and CFV flow rate calculations.

This section describes the equations for calculating flow rates from various flow meters. After you calibrate a flow meter according to §1066.650, use the calculations described in this section to calculate flow during an emission test. Calculate flow according to 40 CFR 1065.642 instead if you calculate emissions based on molar flow rates.

(a) PDP volumetric flow rate. Based upon the speed at which you operate the PDP for a test interval, select the corresponding slope, a_1, and intercept, a_0, as calculated in §1066.650(a), to calculate volumetric flow rate, $\dot{Q}$ as follows:

$$\dot{Q} = f_{\text{nPDP}} \cdot \frac{V_{\text{rev}} \cdot T_{\text{std}} \cdot p_{\text{in}}}{T_{\text{in}} \cdot p_{\text{std}}}$$

Eq. 1066.652-1

Where:

f_{nPDP} = pump speed.

V_{rev} = PDP volume pumped per revolution.

T_{std} = standard temperature = 293.15 K.

p_{in} = mean static absolute pressure at the PDP inlet.

T_{in} = pump inlet absolute temperature.

p_{std} = standard pressure= 101.325 kPa.

p_{out} = mean static absolute pressure at the PDP outlet

$$V_{\text{rev}} = \frac{a_1}{f_{\text{nPDP}}} \cdot \sqrt{\frac{p_{\text{out}} - p_{\text{in}}}{p_{\text{out}}}} + a_0$$

Eq. 1066.652-2

Example:

a_1 = 50.43 m^3/min = 0.8405 m^3/s

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T_{std} = standard temperature.¶
f_{nPDP} = pump speed.¶

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p_{in} = pump inlet absolute static pressure.¶

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f_{nPDP} = 755.0 r/min = 12.58 r/s
p_{out} = 99.950 kPa
p_{in} = 98.575 kPa
a_0 = 0.056 m³/r
T_{in} = 323.5 K

$$V_{rev} = \frac{0.8405}{12.58} \cdot \sqrt{\frac{99.950 - 98.575}{99.950}} + 0.056$$

V_{rev} = 0.063 m³/r

$$\dot{Q} = 12.58 \cdot \frac{0.06383 \cdot 293.15 \cdot 98.575}{323.5 \cdot 101.3}$$

$\dot{Q}$ = 0.7079 m³/s

(b) SSV volumetric flow rate. Based on the C_d versus $Re^{\#}$ equation you determined according to §1066.650(b), calculate SSV volumetric flow rate, V_{mix}, during an emission test as follows:

$$\dot{Q} = \frac{K_q}{\rho_s} \cdot \frac{C_d \cdot Y \cdot d_t^{\,2}}{\sqrt{1-\beta^4}} \cdot \sqrt{\rho_1 \cdot \Delta p}$$

Eq. 1066.652-3

Where:

$\dot{Q}$ = air flow rate of flow meter, scfm (m³/min).

K_q = 0.0021074 for SI units; = 1 for English units.

ρ_s = density of air at standard conditions = 1.2041 kg/m³.

C_d = discharge coefficient.

Y = Expansion factor, as determined in paragraph (b)(1) of this section.

d_t = venturi throat diameter, inch (mm).

β = ratio of venturi throat diameter to approach pipe diameter.

ρ_1 = density of air at inlet conditions, lbm/ft³ (kg/m³), as determined in paragraph (b)(2) of this section.

Δp = pressure drop between inlet and throat, inches H_2O (kPa).

(1) The expansion factor (Y) is calculated as follows:

$$Y = \left[r^{\frac{2}{k}} \cdot \left(\frac{k}{k-1}\right) \cdot \left(\frac{1-r^{\left(\frac{k-1}{k}\right)}}{1-r}\right) \cdot \left(\frac{1-\beta^4}{1-\beta^4 \cdot r^{\frac{2}{k}}}\right) \right]^{\frac{1}{2}}$$

Eq. 1066.652-4

Where:

$$r = 1 - \frac{\Delta p}{p_{abs}}$$

$$\beta = \frac{d}{D}$$

d = venturi throat diameter in inches (m).

D = inlet pipe diameter in inches (m).

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k = ratio of specific heats (1.40 for air).

(2) Calculate the inlet density ρ_1, as follows:

$$\rho_1 = \frac{p_{abs}}{R_{mix} \cdot T_{abs}}$$

Eq. 1066.652-5

Where:

p_{abs} = p_1 + atmospheric pressure.

T_{in} = venturi inlet absolute temperature.

$$R_{mix} = \frac{8.3144 \text{ kJ/(kg} \cdot \text{mol} \cdot \text{K)}}{MW_{mix}}$$

MW_{mix} = the molecular weight of the mix, as calculated in paragraph (b)(3) of this section.

(3) Calculate the molecular weight of the mix as follows:

$$MW_{mix} = \frac{MW_{air} \cdot (p_{abs} - p_v) + MW_{H_2O} \cdot p_v}{p_{abs}}$$

Eq. 1066.652-6

Where:

MW_{air} = 28.964 kg/mol

p_{abs} = ?p_v = vapor pressure, in Hg (kPa)

MW_{H20} = 18.015 kg/mol

(c) CFV volumetric flow rate. Some CFV flow meters consist of a single venturi and some consist of multiple venturis, where different combinations of venturis are used to meter different flow rates. If you use multiple venturis and you calibrated each venturi independently to determine a separate calibration coefficient, K_v, for each venturi, calculate the individual volumetric flow rates through each venturi and sum all their flow rates to determine $\dot{Q}$. If you use multiple venturis and you calibrated each combination of venturis, calculate $\dot{Q}$ using the K_v that was determined for that combination of venturis.

(1) To calculate volumetric flow rate through one venturi or a combination of venturis, use the mean K_v you determined according to §1066.650(c) and calculate the appropriate volumetric flow rate, $\dot{Q}$, during an emission test as follows:

$$\dot{Q} = \frac{K_v \cdot p_{in}}{\sqrt{T_{in}}}$$

Eq. 1066.652-7

Where:

$\dot{Q}$ = air flow rate of flow meter, in m^3/s.

K_v = flow meter calibration coefficient, in $m^3 \cdot K^{1/2}/(kPa \cdot s)$.

T_{in} = temperature at the venturi inlet, in K.

p_{in} = absolute static pressure at the venturi inlet, in kPa.

Example:

K_v = 0.074954 $m^3 \cdot K^{1/2}/(kPa \cdot s)$

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(4) The density at standard conditions of 101.33 kPa and 20 °C is calculated as follows:¶

$$\rho_s = \frac{101.325}{\frac{8.314472}{28.96559} \cdot 293.15} = 1.2041 \text{ kg/}$$

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$p_{in} = 99.654$ kPa

$T_{in} = 353.15$ K

$$\dot{Q} = \frac{0.074954 \cdot 99.654}{\sqrt{353.15}}$$

$\dot{Q} = 0.39748\ \mathrm{m^3/s}$

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§1066.665 NMOG determination.

For vehicles subject to an NMOG standard, determine NMOG as described in paragraph (a) of this section. Except as specified in the standard-setting part, you may alternatively calculate NMOG results based on measured NMHC emissions as described in paragraphs (c) through (f) of this section.

(a) Determine NMOG by independently measuring alcohols and carbonyls as described in 40 CFR 1065.805 and 1065.845. Use good engineering judgment to determine which alcohols and carbonyls you need to measure. This would typically require you to measure all alcohols and carbonyls that you expect to contribute 1% or more of total NMOG emissions. Calculate NMOG with the following equation, using density values specified in §1066.1005(f):

$$m_{\mathrm{NMOG}} = m_{\mathrm{NMHC}} - \rho_{\mathrm{NMHC}} \cdot \sum_{i=1}^{N} \frac{m_{\mathrm{OHC}i}}{\rho_{\mathrm{OHC}i}} \cdot RF_{\mathrm{OHC}i[\mathrm{THC\text{-}FID}]} + \sum_{i=1}^{N} m_{\mathrm{OHC}i}$$

Eq. 1066.665-1

Where:

m_{NMOG} = the sum of the mass of NMOG in the exhaust.

m_{NMHC} = the mass of NMHC and all oxygenated hydrocarbons (OHCs) in the exhaust, as determined using Eq. 1066.610-1. Calculate NMHC mass based on ρ_{NMHC}.

ρ_{NMHC} = the effective C_1-equivalent density of NMHC as specified in §1066.1005(f).

$m_{\mathrm{OHC}i}$ = the mass of oxygenated species *i* in the exhaust calculated using Eq. 1066.610-1.

$\rho_{\mathrm{OCH}i}$ = the C_1-equivalent density of oxygenated species *i*.

$RF_{\mathrm{OHC}i[\mathrm{THC\text{-}FID}]}$ = The response factor of a THC-FID to oxygenated species *i* relative to propane on a C_1-equivalent basis as determined in 40 CFR 1065.665.

(b) The following example shows how to determine NMOG emissions as described in paragraph (a) of this section for (OHC) compounds including ethanol (C_2H_5OH), methanol (CH_3OH), acetaldehyde (C_2H_4O), and formaldehyde (C_2HO) as C_1-equivalent concentrations:

m_{NMHC} = 0.0125 g

m_{CH3OH} = 0.0002 g

m_{C2H5OH} = 0.0009 g

m_{HCHO} = 0.0001 g

m_{C2H4O} = 0.00005 g

$RF_{\mathrm{CH3OH[THC\text{-}FID]}}$ = 0.63

$RF_{\mathrm{C2H5OH[THC\text{-}FID]}}$ = 0.75

$RF_{\mathrm{HCHO[THC\text{-}FID]}}$ = 0.00

$RF_{\mathrm{C2H4O[THC\text{-}FID]}}$ = 0.50

$\rho_{\mathrm{NMHC\text{-}liq}}$ = 576.816 g/m^3

ρ_{CH3OH} = 1332.02 g/m^3

ρ_{C2H5OH} = 957.559 g/m^3

ρ_{HCHO} = 1248.21 g/m^3

ρ_{C2H4O} = 915.658 g/m^3

$$m_{\mathrm{NMOG}} = 0.0125 - 576.816 \cdot \left(\begin{array}{l} \frac{0.0002}{1332.02} \cdot 0.63 + \frac{0.0009}{957.559} \cdot 0.75 + \\ \frac{0.0001}{1248.21} \cdot 0.00 + \frac{0.00005}{915.658} \cdot 0.5 \end{array} \right) + \\ 0.0002 + 0.0009 + 0.0001 + 0.00005$$

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Table 1 of §1066.665–Default values for THC FID ¶ response factor relative to propane on a C_1-equivalent basis¶
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$m_{\mathrm{NMOG}} = 0.013273$

(c) For ethanol-gasoline blends less than 25 % ethanol by volume, you may calculate NMOG emissions from measured NMHC emissions as follows:

(1) For hot start and hot running test cycles or intervals other than the FTP, you may determine NMOG based on the test cycle NMHC emission rate using the following equation:

$$e_{\mathrm{NMOGhot}} = e_{\mathrm{NMHChot}} \cdot 1.03$$

Eq. 1066.665-2

Where:

e_{NMOGhot} = mass emission rate of NMOG over the hot running test cycle.

e_{NMHChot} = mass emission rate of NMHC over the hot running test cycle, calculated using $\rho_{\mathrm{NMHC\text{-}liq}}$.

Example:

$e_{\mathrm{NMHChot}} = 0.025$ g/mi

$$e_{\mathrm{NMOGhot}} = 0.025 \cdot 1.03 = 0.026 \text{ g/mi}$$

(2) You may determine weighted composite NMOG for FTP testing based on the weighted composite NMHC emission rate and the volume percent of ethanol in the fuel using the following equation:

$$e_{\mathrm{NMOGcomp}} = e_{\mathrm{NMHCcomp}} \cdot \left(1.0302 + 0.0071 \cdot VP_{\mathrm{EtOH}}\right)$$

Eq. 1066.665-3

Where:

e_{NMOGcomp} = weighted composite mass emission rate of NMOG.

e_{NMHCcomp} = weighted composite mass emission rate of NMHC, calculated using $\rho_{\mathrm{NMHC\text{-}liq}}$.

VP_{EtOH} = volume percentage of ethanol in the test fuel. Use good engineering judgment to determine this value either as specified in 40 CFR 1065.710 or based on blending volumes, taking into account any denaturant.

Example:

$e_{\mathrm{NMHCcomp}} = 0.025$ g/mi

$VP_{\mathrm{EtOH}} = 15.1$ %

$$e_{\mathrm{NMOGcomp}} = 0.025 \cdot \left(1.0302 + 0.0071 \cdot 15.1\right) = 0.0284 \text{ g/mi}$$

(3) You may determine NMOG for the complete FTP cold start test interval for use in fuel economy and CREE calculations based on the NMHC emission rate for the test interval and the volume percent of ethanol in the fuel using the following equation:

$$e_{\mathrm{NMOG\text{-}FTPct}} = e_{\mathrm{NMHC\text{-}FTPct}} \cdot \left(1.0246 + 0.0079 \cdot VP_{\mathrm{EtOH}}\right)$$

Eq. 1066.665-4

Where:

$e_{\mathrm{NMOG\text{-}FTPct}}$ = mass emission rate of NMOG over the FTP cold start test interval.

$e_{\mathrm{NMHC\text{-}FTPct}}$ = mass emission rate of NMHC over the FTP cold start test interval, calculated using $\rho_{\mathrm{NMHC\text{-}liq}}$.

VP_{EtOH} = volume percentage of ethanol in the test fuel.

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Example:

$e_{\text{NMHC-FTPct}}$ = 0.052 g/mi

VP_{EtOH} = 15.1 %

$$e_{\text{NMOG-FTPct}} = 0.052 \cdot (1.0246 + 0.0079 \cdot 15.1) = 0.0595 \text{ g/mi}$$

(4) You may determine NMOG for the FTP stabilized test interval for either the cold start or hot start test for use in fuel economy and CREE calculations based on the NMHC emission rate for the test interval and the volume percent of ethanol in the fuel using the following equation:

$$e_{\text{NMOG-FTPcs-hs}} = e_{\text{NMHC-FTPcs-hs}} \cdot (1.1135 + 0.001 \cdot VP_{\text{EtOH}})$$

Eq. 1066.665-5

Where:

$e_{\text{NMOG-FTPcs-hs}}$ = mass emission rate of NMOG over the FTP stabilized test interval.

$e_{\text{NMHC-FTPcs-hs}}$ = mass emission rate of NMHC over the FTP stabilized test interval, calculated using $\rho_{\text{NMHC-liq}}$.

VP_{EtOH} = volume percentage of ethanol in the test fuel.

(5) You may determine NMOG for the complete FTP hot start test interval for use in fuel economy and CREE calculations based on the NMHC emission rate for the test interval and the volume percent of ethanol in the fuel using the following equation:

$$e_{\text{NMOG-FTPht}} = e_{\text{NMHC-FTPht}} \cdot (1.0195 + 0.0031 \cdot VP_{\text{EtOH}})$$

Eq. 1066.665-6

Where:

$e_{\text{NMOG-FTPht}}$ = mass emission rate of NMOG over the FTP hot start test interval.

$e_{\text{NMHC-FTPht}}$ = mass emission rate of NMHC over the FTP hot start test interval, calculated using $\rho_{\text{NMHC-liq}}$.

VP_{EtOH} = volume percentage of ethanol in the test fuel.

(d) You may take the following additional steps when determining fuel economy and CREE under 40 CFR part 600:

(1) Calculate NMOG by interval using Eq. 1066.665-3 for individual bag measurements from the FTP.

(2) Calculate NMOG for two-bag FTPs using Eq. 1066.665-3 for hybrid-electric vehicles as described in 40 CFR 600.114.

(e) We consider NMOG emission values for diesel-fueled vehicles to be equivalent to NMHC emission values for all test cycles. Follow paragraph (f) of this section for natural gas fueled vehicles with diesel pilot injection.

(f) For all fuels not covered by paragraphs (c) and (e) of this section, manufacturers may propose a methodology to calculate NMOG results from measured NMHC emissions. We will approve adjustments based on comparative testing that demonstrates how to properly represent NMOG based on measured NMHC emissions.

§1066.695 Data requirements.

Record the following information for each test:

(a) Test number.

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(b) A brief description of the test vehicle (or other system/device tested).
(c) Date and time of day for each part of the test sequence.
(d) Test results. Also include a validation of driver accuracy as described in §1066.430(j).
(e) Driver and equipment operators.
(f) Vehicle information as applicable, including identification number, model year, applicable emission standards, vehicle model, test group, durability group, engine family, evaporative/refueling emission family, basic engine description (including displacement, number of cylinders, turbo-/supercharger used, and catalyst type), fuel system (type of fuel injection and fuel tank capacity and location), engine code, gross vehicle weight rating, equivalent test weight, inertia weight class, actual curb weight at zero miles, actual road load at 50 mph, transmission configuration, axle ratio, odometer reading, idle rpm, and drive wheel tire pressure.
(g) Dynamometer identification, inertia weight setting, indicated power absorption setting, and records to verify compliance with the driving distance and cycle-validation criteria as calculated from measured roll or shaft revolutions.
(h) Analyzer bench identification, analyzer ranges, recordings of analyzer output during zero, span, and sample readings.
(i) Associate the following information with the test record: test number, date, vehicle identification, vehicle and equipment operators, and identification of the measurements recorded.
(j) Test cell barometric pressure and humidity. You may use a central laboratory barometer if the barometric pressure in each test cell is shown to be within ±0.1 % of the barometric pressure at the central barometer location.
(k) Records to verify compliance with the ambient temperature requirements throughout the test procedure and records of fuel temperatures during the running loss test.
(l) [Reserved]
(m) For CVS systems record, dilution factor for each interval of the exhaust test and the following additional information:
(1) CFV and SSV V_{mix} for each interval of the exhaust test.
(2) PDP. Test measurements required to calculate V_{mix} for each interval of the exhaust test.
(n) The humidity of the dilution air if you remove H_2O from an emission sample before measurement.
(o) Temperature of the dilute exhaust mixture and secondary dilution air (in the case of a double-dilution system) at the inlet to the respective gas meter or flow instrumentation used for particulate sampling.
(p) The maximum gas temperature over the course of the test within 20 cm upstream or downstream of the sample media (e.g., filter).
(q) If applicable, the temperature of the heated FID, the gas in the heated sample line, and the heated filter.
(r) Gas meter or flow measurement instrumentation readings at the start and end of each test interval.
(s) The stabilized pre-test weight and post-test weight of each particulate sample media (e.g., filter).
(t) Continuous temperature and humidity of the ambient air in which the particulate sample media (e.g., filter).are stabilized.
(u) For vehicles fueled by natural gas, the test fuel composition, including all carbon-containing compounds (except CO); e.g. CO_2, of the natural gas-fuel used during the test. Record C_1 and C_2

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compounds individually. You may record C_3 through C_5 hydrocarbons together, and you may record C_6 and heavier hydrocarbon compounds together.

(v) Additional required records for liquefied petroleum gas-fueled vehicles. For vehicles fueled by liquefied petroleum gas, the test fuel composition, including all carbon-containing compounds (except CO); e.g. CO_2. Each hydrocarbon compound present, through C_4 compounds, shall be individually reported. C_5 and heavier hydrocarbons may be reported as a group. Record C_1 and C_4 compounds individually. You may record C_5 and heavier hydrocarbon compounds together.

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Subpart H—Cold-Temperature Test Procedures

§1066.701 Applicability and general provisions.

(a) The procedures of this part 1066 may be used for testing at any ambient temperature. The standard-setting part may specify additional provisions for testing conducted at temperatures below 20 °C (68 °F). See, for example, 40 CFR part 86, subpart C, for testing related to exhaust emission standards and 40 CFR part 600 for calculating fuel economy for light-duty motor vehicles. See the standard-setting part to determine if your vehicle is required to meet emission standards outside the normal (20 to 30) °C (68 to 86 °F) temperature range.

(b) Do not apply the humidity correction factor in §1066.630(a) for cold-temperature testing.

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Subpart I—Exhaust Emission Test Procedures for Motor Vehicles

§1066.801 Applicability and general provisions.

This subpart I specifies how to apply the test procedures of this part for motor vehicles at or below 14,000 pounds GVWR, including light-duty vehicles, light-duty trucks, and heavy-duty vehicles at or below 14,000 pounds GVWR that are subject to chassis testing for exhaust emissions.

(a) Use the procedures detailed in this subpart to measure vehicle emissions over a specified drive schedule in conjunction with subpart E of this part. Where the procedures of subpart E of this part differ from this subpart I, the provisions in this subpart I take precedence.

(b) Collect samples of every pollutant for which an emission standard applies, unless specified otherwise.

(c) This subpart covers the following test procedures:

(1) General driving represented by the Federal Test Procedure (FTP). This procedure is also used for measuring evaporative emissions. This may be called the conventional test since it was first adopted for the earliest emission standards.

(i) The FTP consists of one Urban Dynamometer Driving Schedule (UDDS) as specified in paragraph (a) of Appendix I of 40 CFR part 86, followed by a 10-minute soak with the engine off and repeat driving through the first 505 seconds of the UDDS. The UDDS represents about 7.5 miles of driving in an urban area. FTP measurements consist of a cold-start test and a hot-start test. Engine startup (with all accessories turned off), operation over the initial UDDS, and engine shutdown make a complete cold-start test. The hot-start test consists of the first 505 seconds of the UDDS following the 10-minute soak and a hot-running portion of the UDDS after the first 505 seconds. The hot-running portion is generally measured during the cold-start test; however, in certain cases, the hot-start test may involve a second full UDDS following the 10-minute soak.

(ii) Evaporative testing consists of a preconditioning drive with the UDDS and the FTP driving schedule (including exhaust measurement) as described in 40 CFR 86.133-96, followed by emission measurements in a sealed enclosure. The running loss test consists of a UDDS, then two New York City Cycles as specified in paragraph (f) of Appendix I of 40 CFR part 86, followed by another UDDS as described in 40 CFR 86.134-96. The New York City Cycle represents about 1.7 miles of driving in a city center.

(iii) Refueling emission testing consists of preconditioning and purge drives using UDDS and FTP cycles as described in 40 CFR 86.146 through 86.154.

(2) Supplemental testing that measures the emission effects from more aggressive driving and operation with the vehicle's air conditioner. This Supplemental Federal Test Procedure (SFTP) is based on a composite of three different duty cycles. In addition to the FTP measurements, vehicles generally operate over the US06 and SC03 driving schedules as specified in paragraphs (g) and (h) of Appendix I of 40 CFR part 86, respectively. In the case of heavy-duty vehicles above 10,000 pounds GVWR and at or below 14,000 pounds GVWR, SFTP testing involves additional driving over the LA-92 driving schedule specified in paragraph (c) of 40 CFR part 86, Appendix I, instead of the US06 driving schedule. The US06 cycle represents about 8.0 miles of relatively aggressive driving. The SC03 cycle represents about 3.6 miles of urban driving with the air conditioner operating. The LA-92 cycle represents approximately 9.8 miles of relatively aggressive driving for commercial trucks.

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(3) The Highway Fuel Economy Test (HFET). The HFET, specified in Appendix I of 40 CFR part 600, is designated to simulate rural and freeway driving with an average speed of 48.6 mph and a maximum speed of 60.0 mph. The cycle is 10.2 miles long.
(4) Cold-temperature testing. Cold-temperature standards apply for CO and NMHC emissions when vehicles operate over the FTP at a nominal temperature of 20 °F.
(5) Air conditioning credits for greenhouse gas standards. Vehicles operate over repeat runs of the AC17 test sequence to allow for calculating credits as part of demonstrating compliance with CO_2 emission standards. The AC17 test sequence consists of a UDDS preconditioning drive, followed by emission measurements over the SC03 and HFET driving schedules.
(d) Starting in model year 2022, speed tolerances and cycle-validation criteria apply as specified in 40 CFR part 1066, subpart E; however, for road load power determination in §1066.810, vehicle preconditioning, fuel dispensing spitback in 40 CFR 86.146, and canister purging in 40 CFR 86.153-98(d), the upper and lower speed tolerances are ±4.0 mph. Up to three additional occurrences of speed variations greater than the tolerance are acceptable for road load power determination in §1066.810 and canister purging in 40 CFR 86.153-98(d), provided they occur for less than 15 seconds on any occasion, and are clearly documented as to the time and speed at that point of the driving schedule.

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§1066.810 Road load power, test weight, and inertia weight class determination.

(a) Simulate a vehicle's test weight on the dynamometer using the appropriate equivalent test weight shown in Table 1 of this section. Equivalent test weights are established according to each vehicle's test weight basis, as described in paragraph (b) of this section. Table 1 also specifies the inertia weight class corresponding to each equivalent test weight; the inertia weight class allows for grouping vehicles with a range of equivalent test weights. Table 1 follows:

Table 1 of §1066.810–Equivalent test weights (pounds)

Test weight basis	Equivalent test weight	Inertia weight class
Up to 1062	1000	1000
1063 to 1187	1125	1000
1188 to 1312	1250	1250
1313 to 1437	1375	1250
1438 to 1562	1500	1500
1563 to 1687	1625	1500
1688 to 1812	1750	1750
1813 to 1937	1875	1750
1938 to 2062	2000	2000
2063 to 2187	2125	2000
2188 to 2312	2250	2250
2313 to 2437	2375	2250
2438 to 2562	2500	2500
2563 to 2687	2625	2500
2688 to 2812	2750	2750
2813 to 2937	2875	2750

2938 to 3062	3000	3000
3063 to 3187	3125	3000
3188 to 3312	3250	3000
3313 to 3437	3375	3500
3438 to 3562	3500	3500
3563 to 3687	3625	3500
3688 to 3812	3750	3500
3813 to 3937	3875	4000
3938 to 4125	4000	4000
4126 to 4375	4250	4000
4376 to 4625	4500	4500
4626 to 4875	4750	4500
4876 to 5125	5000	5000
5126 to 5375	5250	5000
5376 to 5750	5500	5500
5751 to 6250	6000	6000
6251 to 6750	6500	6500
6751 to 7250	7000	7000
7251 to 7750	7500	7500
7751 to 8250	8000	8000
8251 to 8750	8500	8500
8751 to 9250	9000	9000
9251 to 9750	9500	9500
9751 to 10250	10000	10000
10251 to 10750	10500	10500
10751 to 11250	11000	11000
11251 to 11750	11500	11500
11751 to 12250	12000	12000
12251 to 12750	12500	12500
12751 to 13250	13000	13000
13251 to 13750	13500	13500
13751 to 14000	14000	14000

(b) The test weight basis for non-MDPV heavy-duty vehicles is adjusted loaded vehicle weight, as defined in 40 CFR 86.1803. For all other vehicles, the test weight basis for establishing equivalent test weight is loaded vehicle weight, as defined in 40 CFR 86.1803.

(c) For each test vehicle subject to FTP and SFTP standards, determine road load forces at speeds between 10 and 70 miles per hour. The road load force must represent vehicle operation on a smooth level road with no wind or calm winds, no precipitation, an ambient temperature of approximately 20 °C (68 °F), and atmospheric pressure of 98.21 kPa. You may extrapolate road load force for speeds below 10 mph.

§1066.812 Test sequence; general requirements.

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(1) For heavy light-duty trucks (LDT3 and LDT4), test weight basis is adjusted loaded vehicle weight for emission tests and loaded vehicle weight for fuel economy tests. Manufacturers may choose instead to perform fuel economy tests at adjusted loaded vehicle weight. Weight terms are defined in 40 CFR 86.1803.
(2) For MDPVs and heavy-duty vehicles, test weight basis is adjusted loaded vehicle weight.

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(a) The following provisions apply for all testing:
(1) Ambient temperatures encountered by the test vehicle must be (20 to 30) °C, unless otherwise specified. For vehicle soaking steps, the soak period may be interrupted once for up to 10 minutes to transport the vehicle from one soak area to another, as long as the ambient temperature experienced by the vehicle is never below 20 °C. The temperatures monitored during testing must be representative of those experienced by the test vehicle.
(2) Use good engineering judgment to ensure that the vehicle remains approximately level throughout testing to prevent abnormal fuel distribution.
(3) If a test is void after collecting emission data from previous test segments, the test may be repeated to collect only those data points needed to complete emission measurements. You may combine emission measurements from different test runs to demonstrate compliance with emission standards.
(b) FTP testing consists of a sequence of steps for measuring both exhaust and evaporative emissions. Evaporative testing involves both a two-day test sequence and a three-day test sequence as shown in Figure 1 of this section. For vehicles with no evaporative canister, this defaults to a single test sequence for measuring FTP exhaust emissions. Evaporative test procedures are described in detail in 40 CFR part 86, subpart B.
(c) Test procedures for onboard refueling vapor recovery are described in 40 CFR 86.150 through 86.157. This testing is also integral with the FTP test sequence. Fuel spitback testing is conducted as a stand-alone test as described in 40 CFR 86.146.
(d) SFTP testing is performed as described in §§1066.830 through 1066.832. This testing may be performed in any sequence that follows the preconditioning protocol described in §1066.831.

Figure 1 of §1066.812–Federal test procedure test sequence.

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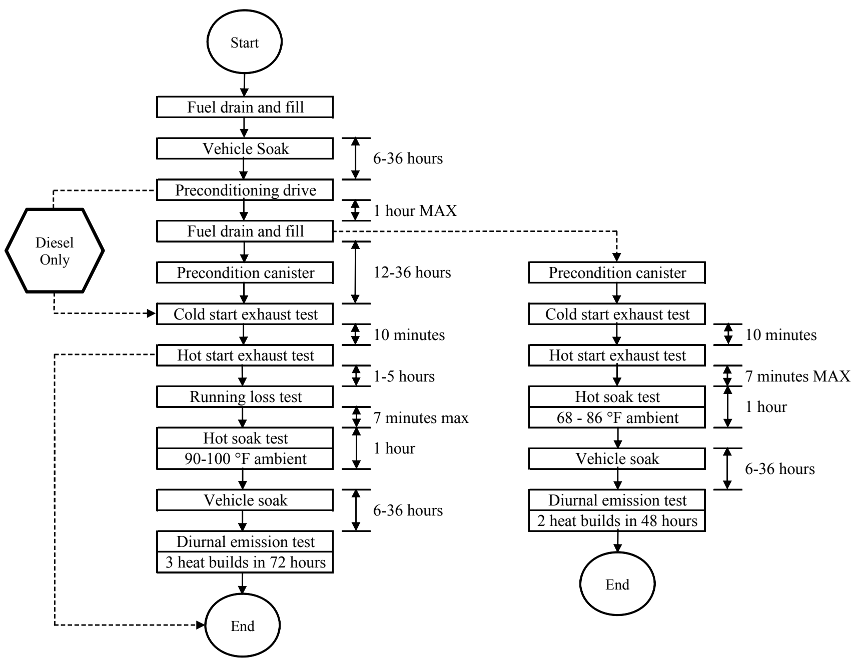

§1066.814 Vehicle preparation.

(a) For vehicles subject to running loss testing, prepare the fuel tank(s) for recording the temperature of the test fuel, as described in 40 CFR 86.107–98(e).

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

(c) For preconditioning that involves loading evaporative emission canister with butane, provide valving or other means as necessary to allow purging and loading of the canister.

(d) For vehicles to be tested for running loss emissions according to 40 CFR 86.134-96, prepare the fuel tank for measuring and recording the temperature and pressure of the fuel tank as specified in 40 CFR 86.107–98(e) and (f). Vapor temperature measurement is optional during the running loss test. If vapor temperature is not measured, fuel tank pressure need not be measured.

(e) For vehicles to be tested for running loss emissions according to 40 CFR 86.134-96, prepare the exhaust system by sealing or plugging all detectable sources of exhaust gas leaks. Inspect or test the exhaust system to ensure that no detectable exhaust hydrocarbons are emitted into the running loss enclosure during testing.

(f) The following provisions apply for preconditioning steps to reduce nonfuel emissions to normal vehicle background levels for vehicles subject to Tier 3 evaporative emission standards under 40 CFR 86.1813:

(1) Manufacturers must notify us in advance if they plan to perform such preconditioning. This notice must include a detailed description of the intended procedures and any measurements or

thresholds for determining when stabilization is complete. Manufacturers need not repeat this notification for additional vehicle testing in the same or later model years as long as the preconditioning practice conforms to these procedures.
(2) Manufacturers may precondition a vehicle as described in paragraph (f)(1) of this section only within 12 months after the vehicle's original date of manufacture, except they may remove the spare tire for any testing.

§1066.820 Exhaust emission test procedures for FTP testing.
(a) General. The dynamometer run consists a cold start testing and hot start testing. Cold start testing begins after a 12 to 36 hour soak according to the provisions of 40 CFR 86.132. Hot start testing begins 10 minutes after the end of the cold start UDDS. See §1066.801 for further information on the driving schedules.
(b) PM sampling options. You may collect PM using any of the procedures specified in paragraphs (b)(1) through (5) of this section, taking into account the FTP composite emission calculations in §1066.822. Testing must meet the requirements related to filter face velocity as described in 40 CFR 1065.170(c)(1)(vi), except where flow weighting is allowed. If a procedure is chosen that allows flow weighting, set the filter face velocity of weighting targets of 1.0 to meet the requirements of 40 CFR 1065.170(c)(1)(vi) and allow filter face velocity to decrease as a percentage of the weighting factor for weighting factors that are less than 1.0. Use the appropriate *DF* equations in §1066.620 to show that you meet the dilution factor requirements of §1066.110(b)(2)(iii)(B).
(1) You may collect a separate PM sample for each test interval of the FTP.
(2) You may collect PM on one filter over the cold start UDDS and on a separate filter over the hot start UDDS.
(3) You may collect PM on one filter over the cold start UDDS (bags 1 and 2) and on a separate filter over the 867 seconds of the stabilized portion of the cold start UDDS and the first 505 seconds of the hot start UDDS (bags 2 and 3). Note that this option involves duplicate measurements during the stabilized portion of the cold start UDDS.
(4) You may collect PM on a single filter over the cold start UDDS and the first 505 seconds of the hot start UDDS. If you choose this option, you must adjust your sampling system flow rate to weight the filter face velocity over the three intervals of the FTP, based on weighting targets of 0.43 for bag 1, 1.0 for bag 2, and 0.57 for bag 3.
(5) You may collect PM on a single filter over the cold start UDDS and the full hot start UDDS. If you choose this option, you must adjust your sampling system flow rate to weight the filter face velocity, based on weighting targets of 0.754 for the cold start UDDS and 1.0 for the hot start UDDS.
(c) Test sequence. Perform FTP testing in the following sequence:
(1) Start sampling and recording simultaneously with starting the vehicle.
(2) Fifteen seconds after the engine starts, place the transmission in gear.
(3) Twenty seconds after the engine starts, begin the initial vehicle acceleration of the driving schedule.
(4) Operate the vehicle over the remainder of the UDDS as described in §1066.801.
(5) At the end of the deceleration scheduled to occur 505 seconds into the cold start UDDS, simultaneously switch all the sample flows from the cold start transient interval to the stabilized interval, stopping all cold start transient interval sampling and recording, including background

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(4) You may collect PM on one filter over the cold start UDDS (bags 1 and 2) and on a separate filter over the 867 seconds of the stabilized portion of the cold start UDDS and the first 505 seconds of the hot start UDDS (bags 2 and 3) Note that this option involves duplicate measurements during the stabilized portion of the cold start UDDS.¶

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sampling. Reset integrating devices for the stabilized interval and indicate the end of the cold start interval in the recorded data.
(6) Turn the engine off 2 seconds after the end of the last deceleration in the stabilized interval (1,369 seconds after the start of the test cycle).
(7) Five seconds after the engine stops running, stop all stabilized interval sampling and recording, including background sampling, stop integrating devices for the stabilized interval, and indicate the end of the stabilized interval in the recorded data. Note that the 5 second delay is intended to approximate sampling system transport time.
(8) Take the following steps for the hot start test:
(i) Repeat the steps in paragraphs (c)(1) through (3) of this section. Operate the vehicle over the first 505 seconds of the UDDS as described in §1066.803. Begin hot start testing (9 to 11) minutes after the end of the sample period for the cold start UDDS.
(ii) At the end of the deceleration scheduled to occur 505 seconds into the hot start UDDS, turn off the engine and simultaneously stop all hot start sampling and recording, including background sampling, and integrating devices. As described in §1066.822, hot start testing may in some cases involve driving over the full UDDS as for cold start testing.
(9) This completes the procedures for measuring FTP exhaust emissions. See 40 CFR part 86, subpart B, to continue measurement procedures for evaporative or refueling tests.

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§1066.822 FTP exhaust emission composite calculations.

(a) Determine the mass of exhaust emissions of each pollutant for each interval of FTP testing as described in §1066.610.

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(b) Calculate the final reported test results as a mass-weighted value, $e_{\text{[emission]-FTPcomp}}$, in grams/mile using the following equation:

$$e_{\text{[emission]-FTPcomp}} = 0.43 \cdot \left(\frac{m_{\text{c}}}{D_{\text{ct}} + D_{\text{cs}}} \right) + 0.57 \cdot \left(\frac{m_{\text{h}}}{D_{\text{ht}} + D_{\text{hs}}} \right)$$

Eq. 1066.822-1

Where:
m_{c} = the combined mass emissions determined from the cold start UDDS (generally known as bags 1 and 2), in grams.
D_{ct} = the measured driving distance from the transient portion of the cold start test (bag 1), in miles.
D_{cs} = the measured driving distance from the stabilized portion of the cold start test (bag 2), as applicable, in miles.
m_{h} = the combined mass emissions determined from the hot start UDDS in grams. This is the hot stabilized portion from either the first or second UDDS, if applicable (bag 2 or bag 4), in addition to the hot transient portion (bag 3). See paragraph (d) of this section for special provisions that apply for PM measurement.
D_{ht} = the measured driving distance from the transient portion of the hot start test (bag 3), in miles.
D_{hs} = the measured driving distance from the stabilized portion of the hot start test (bag 4), as applicable, in miles. Set $D_{\text{hs}} = D_{\text{cs}}$ for testing where the hot stabilized portion of the UDDS is not run.
(c) For all pollutants, mass emissions for the cold start UDDS may alternatively be collected separately for the cold start transient portion and the cold stabilized portion, then added together

for a single cold start mass, m_c. Similarly, mass emissions for the hot start UDDS may alternatively be collected separately for the hot start transient portion, then added together with the cold stabilized portion or hot stabilized portion for a single hot start mass, m_h.

(d) Calculate the final reported test results for PM as a mass-weighted value, $e_{PM\text{-}FTPcomp}$, in grams/mile as follows:

(1) Use the following equation for PM measured as described in §1066.820(b)(1):

$$e_{PM\text{-}FTPcomp} = \frac{m_{PM}}{(0.43 \cdot D_{ct}) + D_{cs} + (0.57 \cdot D_{ht})}$$

Eq. 1066.822-2

Where:

m_{PM} = PM mass emissions determined from the test consisting of the cold start UDDS and the first 505 seconds of the hot-start UDDS (bags 1, 2, and 3), in grams per test interval, as calculated using Eq. 1066.610-3.

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(2) Use the following equation for PM measured as described in §1066.820(b)(2):

$$e_{PM\text{-}FTPcomp} = \frac{m_{PM}}{0.43 \cdot (D_{ct} + D_{cs}) + 0.57 \cdot (D_{ht} + D_{hs})}$$

Eq. 1066.822-3

Where:

m_{PM} = PM mass emissions determined from the test consisting of the cold start UDDS and the hot start UDDS (bags 1, 2, 3, and 4), in grams per test interval, as calculated using Eq. 1066.610-4.

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(3) Use the following equation for PM measured as described in §1066.820(b)(3):

$$e_{PM\text{-}FTPcomp} = 0.43 \cdot \left(\frac{m_{PM\text{-}cUDDS}}{D_{ct} + D_{cs}}\right) + 0.57 \cdot \left(\frac{m_{PM\text{-}hUDDS}}{D_{ht} + D_{hs}}\right)$$

Eq. 1066.822-4

Where:

$m_{PM\text{-}cUDDS}$ = PM mass emissions determined from the test consisting of the cold start UDDS (bags 1 and 2), in grams per test interval, as calculated using Eq. 1066.610-2.

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$m_{PM\text{-}hUDDS}$ = PM mass emissions determined from the test consisting of the hot start UDDS (bags 3 and 4), in grams per test interval, as calculated using Eq. 1066.610-2.

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(4) For PM measured as described in §1066.820(b)(4), calculate PM emissions as described in paragraph (d)(3) of this section, except that $m_{PM\text{-}hUDDS}$ is the PM mass emissions determined from the stabilized portion of the cold start UDDS and the first 505 seconds of the hot start UDDS (bags 2 and 3).

§1066.830 Supplemental Federal Test Procedures; overview.

The procedures described in §§1066.831 through 1066.834 describe the Supplemental Federal Test Procedure (SFTP). This testing applies for all vehicles subject to the SFTP standards in 40 CFR part 86, subpart S. The SFTP test procedure consists of two separable test elements: A sequence of vehicle operation with more aggressive driving; and a sequence of vehicle operation that includes the impact of the vehicle's air conditioner.

(a) Collect samples of every pollutant for which an emission standard applies, unless specified otherwise.
(b) The aggressive-driving procedure consists of preconditioning the engine to a hot stabilized condition, after which the vehicle starts operating over the test cycle. For most vehicles, the US06 test cycle applies. Some heavy-duty vehicles operate over a subset of the US06 test cycle, or over the LA-92 test cycle.
(c) The SC03 test procedure in §1066.832 is designed to determine gaseous exhaust emissions while simulating an urban trip on a hot summer day. The full test consists of an engine key-off for 10 minutes following the preconditioning steps, an engine start, and operation over the SC03 test cycle. The provisions of 40 CFR part 86, subpart B, and 40 CFR part 600 waive SC03 testing for some vehicles; in those cases, SFTP composite emissions are calculated by adjusting the weighting calculation.
(d) The SFTP standard applies as a composite representing the constituent test cycles. The emission results from the aggressive driving test element (§1066.831), the air conditioning test element (§1066.832), and the FTP test element (§1066.812 (a) through (d) and (f)) are analyzed according to the calculation methodology and compared to the applicable SFTP emission standards in 40 CFR part 86, subpart S.
(e) The SFTP elements may be run in any sequence that maintains the applicable preconditioning steps specified in §86.816.

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§1066.831 Exhaust emission test procedures for aggressive driving.
(a) Perform testing as described in this section using the US06 cycle or the LA-92 cycle. The US06 cycle can be divided into two test intervals—the US06 City cycle comprises the combined portions of the cycle from 1 to 130 seconds and from 495 to 596 seconds, and the US06 Highway cycle comprises the portion of the cycle between 130 and 495 seconds. See §1066.801 for further information on the driving schedules. Collect samples of every pollutant for which an emission standard applies, unless specified otherwise.
(b) Prepare test vehicles as described in §1066.814 for the FTP test element. Take the following steps to precondition vehicles for testing under this section:
(1) Drain and refill the vehicle's fuel tank(s) in any of the following cases:
(i) For testing unrelated to FTP or HFET testing.
(ii) For a test element that starts more than 72 hours after the most recent FTP or HFET measurement (with or without evaporative emission measurements).
(iii) For testing in which the test vehicle has not remained in an area where ambient temperatures were within the range specified for testing since the previous FTP or HFET.
(2) Take the following steps to precondition vehicles before the aggressive driving test element:
(i) Keep ambient temperatures within the ranges specified for test measurements throughout the preconditioning sequence.
(ii) Push or drive the test vehicle onto the dynamometer.
(iii) Operate the test vehicle as needed to prepare it for testing and to perform practice runs (for the driver or for sampling equipment). For our testing, we will generally operate the vehicle over the same cycle that will be used for testing in §86.831. You may ask us to perform vehicle preconditioning in a certain way to address fuel effects on adaptive memory systems or other factors. Do not measure emissions during the preconditioning drive.
(iv) Operate the test vehicle one time over one of the driving schedules specified in this paragraph (b)(3). You may ask us to use a particular preconditioning driving schedule if that is

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related to fuel effects on adaptive memory systems. Choose from the following driving schedules:
(A) The first 505 seconds of the UDDS (generally known as bag 1)
(B) The last 866 seconds of the UDDS (generally known as bag 2).
(C) The highway fuel economy test cycle.
(D) US06 cycle or, for heavy-duty vehicles above 10,000 pounds GVWR, just the highway portion of the US06 cycle.
(E) The SC03 test cycle.
(F) The LA-92 test cycle.
(4) Allow the vehicle to idle for (1 to 2) minutes. This leads directly into the test measurements described in §1066.831.
(c) Take the following steps to precondition vehicles before the air conditioning test element:
(1) Keep the vehicle in an environment meeting the conditions described in §1066.833 throughout the preconditioning sequence.
(2) Push or drive the test vehicle onto the dynamometer.
(3) Operate the test vehicle one time over the first 505 seconds of the UDDS (bag 1), the last 867 seconds of the UDDS (bag 2), or the SC03 test cycle. If the air conditioning test sequence starts more than 2 hours after a different exhaust emission test, you may instead operate the vehicle over the full UDDS.
(4) Following the preconditioning drive, turn off the test vehicle and the vehicle cooling fan(s) and allow the vehicle to soak for (9 to 11) minutes. This leads directly into the test measurements described in §1066.832.
(d) For testing based on the full US06 cycle, you may collect emissions as a single test interval, or you may collect emissions from city and highway test intervals separately (see 40 CFR part 600). Take the following steps for separate city and highway measurements:
(1) At 130 seconds, simultaneously stop all "US06 City", and start all "US06 Highway" sampling, recording, and integrating (including background sampling). At 136 seconds (before the acceleration), record the measured dynamometer roll revolutions.
(2) At 495 seconds, simultaneously stop all "US06 Highway", and start all "US06 City" sampling, recording, and integrating (including background sampling). At 500 seconds (before the acceleration), record the measured dynamometer roll revolutions.
(3) Except as specified in paragraph (c)(4) of this section, treat the emissions from the two discrete portions of city driving as a single sample.
(4) If you collect gaseous emissions over two test intervals, you may collect PM as a single test interval over the full US06. If you do, then calculate a composite dilution factor based on city and highway emissions, using equation 1066.620-4, to show that you meet the dilution factor requirements of §1066.110(b)(2)(iii)(B).
(e) For diesel fueled vehicles, measure THC emissions on a continuous basis as described in 40 CFR part 1065. For separate city and highway measurements as described in paragraph (c) of this section, perform separate calculations for each portion of the test cycle.
(f) The provisions of §§1066.410 through 1066.430 apply, subject to the following exceptions and additional provisions:
(1) Following the preconditioning specified in §1066.830, place the vehicle in gear and simultaneously start sampling and recording. Begin the first acceleration 5 seconds after placing the vehicle in gear.
(2) Operate the vehicle over one of the following test cycles:

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(i) For heavy-duty vehicles above 10,000 pounds GVWR, operate the vehicle over the LA-92 driving schedule.
(ii) Heavy-duty vehicles above 8,500 pounds GVWR and at or below 10,000 pounds GVWR may be certified using only the highway portion of the US06 driving schedule. See 40 CFR 86.1816.
(iii) In all other cases, operate the vehicle over the full US06 driving schedule.
(3) Turn the engine off 2 seconds before the end of the driving schedule. Five seconds after the engine stops running, stop all sampling and recording (including background) and stop integrating devices. Indicate the end of the test cycle in the recorded data.
(4) Correct calculated NO_x emissions tests as described in §1066.630(a)(1).

§1066.832 Exhaust emission test procedure for SC03 emissions.
(a) Perform testing as described in this section using the SC03 cycle. See §1066.801 for further information on the driving schedules. Precondition the vehicle in accordance with §1066.831 of this subpart to bring the vehicle to a warmed-up stabilized condition. Section 1066.833 discusses the minimum facility requirements and corresponding control tolerances for air conditioning ambient test conditions.
(b) The provisions of §§1066.410 through 1066.430 apply, subject to the following exceptions and additional provisions:
(1) You may position additional cooling fans to provide sufficient air for vehicle cooling if the vehicle has a rear-mounted engine or if the fan configuration described in §1066.410(b)(1)(iv) is not adequate. The additional cooling fans may have a total capacity up to 2.50 m^3/s; however, you may ask us to approve a greater fan capacity under 40 CFR 1065.10(c)(1) by demonstrating that the greater airflow represents in-use operation in a way that has a meaningful effect on emissions.
(2) Close all the vehicle's windows before testing.
(3) The test cell and equipment must meet the specifications in paragraph (c) of this section. Measure and control ambient conditions as specified in paragraph (d) of this section.
(4) Set the vehicle's air conditioning controls by selecting A/C mode and "maximum", setting airflow to "recirculate" (if so equipped), selecting the highest fan setting, and turning the A/C Temperature to full cool (or 72 °F for automatic systems). Turn the controls to the "on" position before testing so the air conditioning system is active whenever the engine is running.
(5) Initiate data logging, sampling of exhaust gases, and integrating measured values before starting the engine.
(6) Simultaneously start the engine and initiate the driver's trace. Place the vehicle in gear 15 seconds after the engine starts to prepare for the initial acceleration. Follow the SC03 driving schedule.
(7) Turn the engine off 2 seconds before the end of the driving schedule. Five seconds after the engine stops running, stop all sampling and recording (including background) and stop integrating devices, indicating the end of the test cycle in the recorded data. Note that the 5 second delay is intended to approximate sampling system transport time.
(8) Correct calculated NO_x emissions as described in §1066.630(a)(2).
(c) Test cell and equipment requirements. (1) Minimum test cell size. The test cell must be at least 20 feet wide, 40 feet long, and 10 feet high, unless we approve the use of a smaller test cell. We will approve this only if you demonstrate that the smaller test cell is capable of meeting all the requirements of this section.

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(2) Vehicle frontal air flow. Verify that the test configuration meets the requirements of §1066.410(b)(1)(iv) before each test.
(d) Test cell ambient conditions. (1) Ambient air temperature. Measure and record ambient air temperature in the test cell at least once every 30 seconds during the sampling period. Control ambient air temperature during emission sampling to a tolerance of 95 ±5 °F throughout the test and (93 to 97) °F on average.
(2) Ambient humidity. Measure and record ambient humidity in the test cell at least once every 30 seconds during the sampling period. Control ambient air temperature during emission sampling as described in §1066.425(d).
(3) Vehicle preconditioning. Use good engineering judgment to demonstrate that you meet the specified instantaneous temperature and humidity tolerances in paragraphs (c)(1) and (2) of this section at all times before and between emission measurements, except that you may exclude up to 3 minutes over the course of a test sequence to account for vehicle transport and other actions to prepare for testing.
(4) Solar heat load. Simulate solar heating as follows:
(i) You may use a metal halide lamp, a sodium lamp, or a quartz halogen lamp with dichroic mirrors as a radiant energy emitter. We may also approve the use of a different type of radiant energy emitter if you demonstrate that it meets the requirements of this section.
(ii) We recommend achieving radiant heating with spectral distribution characteristics as described in the following table:

Table 1 of §1066.833–Recommended Spectral Distribution

Band width (nm)	Percent of total spectrum	
	Lower limit (%)	Upper limit (%)
<320[a]	—	0
320–400	0	7
400–780	45	55
>780	35	53
[a]Note that you may need to filter the UV region between 280 and 320 nm.		

(iii) Determine radiant energy intensity experienced by the vehicle as the average value between two measurements along the vehicle's centerline, one at the base of the windshield and the other at the bottom of the rear window (or equivalent location for vehicles without a rear window). This value must be 850 ±45 W/m^2. Instruments for measuring radiant energy intensity must meet the following minimum specifications:
(A) Sensitivity of 9 microvolts per watt/m^2.
(B) Response time of 1 second.
(C) Linearity of ± 0.5 %.
(D) Cosine of ± 1 % from normalization 0–70 degree zenith angle.
(iv) Check the uniformity of radiant energy intensity at least every 500 hours of emitter usage or every 6 months, whichever is shorter, and after any major modifications affecting the solar simulation. Determine uniformity by measuring radiant energy intensity as described in paragraph (d)(4)(iii) of this section at each point of a 0.5 m grid over the vehicle's full footprint, including the edges of the footprint, at an elevation 1 m above the floor. Measured values of radiant energy intensity must be between (732 and 978) W/m^2 at all points.

§1066.835 AC17 air conditioning efficiency test procedure.

(a) Overview. This section describes a procedure for measuring the net impact of air conditioner operation. See 40 CFR 86.1868 for provisions describing how to use these procedures to calculate credits and otherwise comply with emission standards.

(b) Test cell. Operate the vehicle in a test cell meeting the specifications described in §86.832(c). You may add airflow up to at a maximum of 4 miles per hour during engine idling and when the engine is off if that is needed to meet ambient temperature or humidity requirements. Also, You may position additional cooling fans to provide sufficient air for vehicle cooling if the vehicle has a rear-mounted engine or if the fan configuration described in §1066.410(b)(1)(iv) is not adequate. The additional cooling fans may have a total capacity up to 2.50 m^3/s; however, you may ask us to approve a greater fan capacity under 40 CFR 1065.10(c)(1) by demonstrating that the greater airflow represents in-use operation in a way that has a meaningful effect on emissions.

(c) Ambient conditions. Measure and control ambient conditions as specified in §86.832(d), except that during emission sampling you must target 77 °F throughout the test, your test is not valid if the average value is < 75 °F or > 79 °F, and your instantaneous temperature must be (72 to 82) °F. Also, solar heating is disabled for certain test intervals as described in this section.

(d) Interior air temperature measurement. Measure and record interior air temperature in the test vehicle at least once every 5 seconds during the sampling period. Measure temperature at the outlet of the center-most duct on the dashboard and approximately 30 mm behind the driver and passenger's headrests.

(e) Air conditioning system settings. When vehicle air conditioning is required, set the vehicle's air conditioning controls as follows:

(1) For automatic systems, set the temperature control to 72 °F.

(2) For manual systems, select A/C mode and "maximum", set airflow to "recirculate" (if so equipped), and select the highest fan setting. During the first idle period of the SC03 drive cycle (between 186 and 204 seconds), reduce the fan speed to nominally 50 % of maximum fan speed, set airflow to "fresh air" (if so equipped), and adjust the temperature setting to target a temperature of 55° F at dashboard air outlet.

(f) Test procedure. Follow the procedures specified in §§1066.410 through 1066.430, subject to the following exceptions and additional provisions:

(1) Prepare the vehicle for testing according to 40 CFR 86.132(a) through (g), concluding with a 12 to 36 hour soak.

(2) Open all the vehicle's windows and operate the vehicle over a preconditioning UDDS with no solar heating and with the air conditioning off. At the end of the preconditioning drive, turn off the test vehicle and all cooling fans.

(3) Turn on solar heating within one minute after turning off the engine. Once the solar energy intensity reaches 805 W/m^2, let the vehicle soak for 30 ±1 minutes. You may rely on prior measurements to start the soak period after a defined period of warming up the solar heat load instead of measuring solar energy intensity. Close all of the vehicle's windows at the start of the soak period; ensure that the windows are adequately closed where instrumentation and wiring pass through to the interior.

(4) Initiate data logging, sampling of exhaust gases, and integrating measured values before starting the engine. Start the engine with the air conditioning system already turned on. Operate the vehicle over the SC03 driving schedule. Initiate the driver's trace when the engine starts. Fifteen seconds after the engine starts, place the vehicle in gear and operate the vehicle over the

rest of the driving schedule. At the end of the driving schedule, simultaneously switch all the sampling, recording, and integrating from SC03 to HFET, including background sampling. Indicate the end of the test cycle in the recorded data. Record the measured dynamometer roll revolutions corresponding to the SC03 drive schedule.

(5) Directly following the SC03 drive, operate the vehicle over the HFET driving schedule. Turn the vehicle off at the end of the driving schedule and simultaneously stop all sampling, recording, and integrating, including background sampling. Indicate the end of the test cycle in the recorded data. Record the measured dynamometer roll revolutions corresponding to the HFET drive schedule. Turn off the solar heating.

(6) Allow the vehicle to remain on the dynamometer for (10 to 15) minutes after emission sampling has concluded. Repeat the testing described in paragraphs (f)(1) through (5) of this section, but leave the vehicle's windows open and turn off the vehicle's air conditioner and the solar heating throughout the test run.

(g) Calculations. (1) Determine the mass of exhaust emissions of each pollutant for each interval of AC17 testing as described in §1066.610.

(2) Calculate the final reported mass-weighted emissions of CO_2, $e_{[CO2]\text{-}AC17comp}$, representing the average of the SC03 and HFET emissions, in grams/mile using the following equation:

$$e_{\text{CO2-AC17comp}} = 0.5 \cdot \left(\frac{m_{\text{SC03}}}{D_{\text{SC03}}} \right) + 0.5 \cdot \left(\frac{m_{\text{HFET}}}{D_{\text{HFET}}} \right)$$

Eq. 1066.835-1

Where:

m_{SC03} = Mass emissions from the SC03 test interval, in grams.

m_{HFET} = Mass emissions from the HFET test interval, in grams.

D_{SC03} = The measured driving distance during the SC03 test interval, in miles.

D_{HFET} = The measured driving distance during the HFET test interval, in miles.

(h) Recordkeeping. In addition to the information specified in §1066.695, you must record the following information for each vehicle tested: vehicle class, model type, carline, curb weight, engine displacement, transmission class and configuration, interior volume, climate control system type and characteristics, refrigerant used, compressor type, and evaporator/condenser characteristics.

§1066.839 Highway fuel economy test procedure.

This section provides the test procedure for the highway fuel economy test (HFET). This test involves fuel economy and emission sampling for certain vehicles as described in 40 CFR part 86, subpart S, and in 40 CFR part 600. See §1066.801 for further information on the driving schedules. To perform a test, follow the procedures specified in §§1066.410 through 1066.430, subject to the following exceptions and additional provisions:

(a) Perform the HFET immediately following the FTP when this is practical. If the HFET procedure starts more than 3 hours after an FTP (including evaporative measurements, if applicable), operate it over one UDDS cycle to precondition the vehicle. We may approve additional preconditioning in unusual circumstances.

(b) Operate the vehicle over the Highway Fuel Economy Driving Schedule for preconditioning. Allow the vehicle to idle for 15 seconds (with the vehicle in gear), then start a repeat run of the Highway Fuel Economy Driving Schedule and simultaneously start sampling and recording.

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(c) Turn the engine off at 765 seconds, stop integrating devices and all sampling and recording, including background. Indicate the end of the test cycle in the recorded data.

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§1066.840 Fuel storage system leak test procedure.

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(a) Scope. Verify that there are no significant leaks in your fuel storage system using the leak test described in this section. Perform this check as required in the standard-setting part.

(b) Measurement principles. A leak may be detected by measuring pressure, temperature, and flow to calculate an equivalent orifice diameter for the system. Use good engineering judgment to develop and implement leak test equipment. Your leak test equipment must meet the following requirements:

(1) Pressure, temperature, and flow sensors must be calibrated with NIST-traceable standards.

(2) Correct flow measurements to standard temperature and pressure of 20 °C and 101.325 kPa.

(3) Leak test equipment must have the ability to pressurize fuel storage systems to 4.1 kPa and have an internal leak rate of less than 0.2 slpm.

(4) You must be able to attach the test equipment to the vehicle without permanent alteration of the fuel storage or evaporative emissions control systems.

(5) The point of attachment to the fuel storage system must allow pressurization to test system integrity of the fuel tank and fuel and vapor lines reaching up to and including the gas cap and the evaporative canister. An example of an effective attachment point is the evaporative emission system test port available on some vehicles.

(c) Leak test procedure. Test a vehicle's fuel storage system for leaks as follows:

(1) Fill the vehicle's fuel tank to 40 % capacity.

(2) Soak the vehicle for 6 to 24 hours at a temperature of (20 to 30) °C and maintain this temperature throughout the leak test.

(3) Before performing the test, purge the fuel storage system of any residual pressure, bringing the system into equilibration with the ambient.

(4) Seal the evaporative canister's vent to atmosphere and ensure that the system purge valve is closed.

(5) Attach the leak test equipment to the vehicle.

(6) Pressurize the fuel storage system with N_2 or another inert gas to at least 2.4 kPa. Use good engineering judgment to avoid overpressurizing the system.

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(7) Maintain gas flow through the system for at least 180 seconds, ensuring that the flow reading is stable for an effective leak diameter of ± 0.002 inches.

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(8) Use the following equation, or a different equation you develop based on good engineering judgment, to calculate the effective leak diameter, D_{eff}.

$$D_{eff} = 0.2153 \cdot \left(\frac{V_{gas}}{960 \cdot \sqrt{\frac{(p_1 - p_2)\cdot(p_1 + p_2)}{G \cdot (T + 459.67)}}} \right)^{0.5057}$$

Where:

D_{eff} = Effective leak diameter, rounded to the nearest 0.01 inch.

V_{gas} = Volumetric flow of gas (scfh).

p_1 = Inlet pressure to orifice (psia).

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p_2 = Atmospheric pressure (psia).

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G = Specific gravity of gas at 14.7 psia and 60°F.
T = Temperature of flowing medium (°F).

(9) You may perform any number of replicate tests. The average value of replicate tests is the official result for a given vehicle.
(10) You may use special or alternative test procedures as described in 40 CFR 1065.10(c).
(d) Equipment calibration. Use good engineering judgment to calibrate the leak check device.

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Subpart J—[Reserved]

Subpart K—Definitions and Other Reference Material

§1066.1001 Definitions.

The definitions in this section apply to this part. The definitions apply to all subparts unless we note otherwise. Other terms have the meaning given in 40 CFR part 1065. The definitions follow:

Base inertia means a value expressed in mass units to represent the rotational inertia of the rotating dynamometer components between the vehicle driving tires and the dynamometer torque-measuring device, as specified in §1066.250.

C_1-equivalent means a convention of expressing HC concentrations based on the total number of carbon atoms present, such that the C_1-equivalent of an HC concentration equals the concentration multiplied by the mean number of carbon atoms in each HC molecule. For example, the C_1-equivalent of 10 ppm of propane (C_3H_8) is 30 ppm. C_1-equivalent concentration values may be denoted as "ppmC" in the standard-setting part. Densities may also be expressed on a C_1 basis. Note that calculating HC masses from concentrations and densities is only valid where they are each expressed on the same carbon basis.

Driving schedule means a series of vehicle speeds that a vehicle must follow during a test. Driving schedules are specified in the standard-setting part. A driving schedule may consist of multiple test intervals.

Duty cycle means a set of weighting factors and the corresponding test cycles, where the weighting factors are used to combine the results of multiple test intervals into a composite result.

FTP means one of the following:

(1) The test cycle consisting of one UDDS as specified in paragraph (a) of Appendix I of 40 CFR part 86, followed by a 10-minute soak with the engine off and repeat driving through the first 505 seconds of the UDDS. See §1066.801(c)(1).

(2) The entire test procedure for measuring exhaust and/or evaporative emissions as described in §1066.801(c).

Footprint has the meaning given in the standard-setting part.

HFET means the test cycle specified in Appendix I of 40 CFR part 600.

LA-92 means the test cycle specified in Appendix I, paragraph (c), of 40 CFR part 86.

Nonmethane organic gas (NMOG) means the combination of organic gases other than methane as calculated in §1066.665. Note that for this part, the organic gases are summed on a mass basis without any adjustment for photochemical reactivity.

Parts-per-million (ppm) means ppm on a molar basis. For hydrocarbon concentrations including HC, THC, NMHC, and NMOG, ppm means ppm on a C_1-equivalent molar basis.

Road-load coefficients means sets of A, B, and C road-load force coefficients that are used in the dynamometer road-load simulation, where road-load force at speed v equals $A + B \cdot v + C \cdot v^2$.

SC03 means the test cycle specified in Appendix I, paragraph (h), of 40 CFR part 86.

SFTP means the collection of test cycles as given in 1066.801(c)(2).

Standard reference conditions means the following:

(1) Pressure at 101.325 kPa.

(2) Temperature at 293.15 K.

Test interval means a period over which a vehicle's emission rates are determined separately. For many standards, compliance with the standard is based on a weighted average of the mass emissions from multiple test intervals. For example, the standard-setting part may

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Test weight has the meaning given in §1066.810.

UDDS means the test cycle specified in Appendix I, paragraph (a), of 40 CFR part 86.

US06 means the test cycle specified in Appendix I, paragraph (g), of 40 CFR part 86.

Unloaded coastdown means a dynamometer coastdown run with the vehicle wheels removed from the roll surface.

We (us, our) means the Administrator of the Environmental Protection Agency and any authorized representatives.

§1066.1005 Symbols, abbreviations, acronyms, and units of measure.

The procedures in this part generally follow either the International System of Units (SI) or the United States customary units, as detailed in NIST Special Publication 811, which we incorporate by reference in §1066.1010. See 40 CFR 1065.20 for specific provisions related to these conventions. This section summarizes the way we use symbols, units of measure, and other abbreviations.

(a) Symbols for quantities. This part uses the following symbols and units of measure for various quantities:

Symbol	Quantity	Unit	Unit symbol	Unit in terms of SI base units
α	atomic hydrogen to carbon ratio	mole per mole	mol/mol	1
a	acceleration	feet per second squared or meters per second squared	ft/s^2 or m/s^2	m·s^{-2}
β	atomic oxygen to carbon ratio	mole per mole	mol/mol	1
c	conversion factor			
C_d	discharge coefficient			
d	diameter	meters	m	m
DF	dilution factor			1
e	mass weighted emission result	grams/mile	g/mi	
F	force	pound force or newton	lbf or N	kg·s^{-2}
f	frequency	hertz	Hz	s^{-1}
I	inertia	pound mass or kilogram	lbm or kg	kg
I	current	ampere	A	A
i	indexing variable			
m	mass	pound mass or kilogram	lbm or kg	kg
N	total number in series			
n	total number of pulses in a series			
ρ	mass density	kilogram per cubic meter	kg/m^3	kg·m^{-3}
R	dynamometer roll revolutions	revolutions per minute	rpm	2·π·60^{-1}· m·m^{-1}·s^{-1}
$Re^{\#}$	Reynolds number			
Q	flow	cubic feet or cubic meter		
$\dot{Q}$	flow rate	cfm or cubic meter per second		
p	pressure	pascal	Pa	m^{-1}·kg·s^{-2}
T	Celsius temperature	degree Celsius	°C	K – 273.15

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T	torque (moment of force)	newton meter	N·m	$m^2 \cdot kg \cdot s^{-2}$
t	time	second	s	s
Δt	time interval, period, 1/frequency	second	s	s
U	voltage	volt	V	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
v	speed	miles per hour or meters per second	mph or m/s	$m \cdot s^{-1}$
VP	volume percent			
x	mass of emission over a test interval	kilogram	kg	kg
y	generic variable			

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(b) Symbols for chemical species. This part uses the following symbols for chemical species and exhaust constituents:

Symbol	Species
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
NMHC	nonmethane hydrocarbon
NMHCE	nonmethane hydrocarbon equivalent
NMOG	nonmethane organic gas
NO	nitric oxide
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
N_2O	nitrous oxide
O_2	molecular oxygen
OHC	oxygenated hydrocarbon
PM	particulate matter
THC	total hydrocarbon
THCE	total hydrocarbon equivalent

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(c) Superscripts. This part uses the following superscripts to define a quantity:

Superscript	Quantity
overbar (such as $\bar{y}$)	arithmetic mean

(d) Subscripts. This part uses the following subscripts to define a quantity:

Subscript	Quantity
abs	absolute quantity
act	actual or measured condition
actint	actual or measured condition over the speed interval
atmos	atmospheric
b	base
c	coastdown
comp	composite
cor	corrected
dexh	dilute exhaust quantity
dil	dilute
e	effective

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emission	emission specie
error	error
exh	raw exhaust quantity
exp	expected quantity
fil	filter
final	final
flow	flow measurement device type
i	an individual of a series
int	intake
init	initial quantity, typically before an emission test
max	the maximum (i.e. peak) value expected at the standard over a test interval; not the maximum of an instrument range
meas	measured quantity
ref	reference quantity
rev	revolution
roll	dynamometer roll
s	settling
sat	saturated condition
span	span quantity
std	standard conditions
test	test quantity
uncor	uncorrected quantity
w	weighted
zero	zero quantity

(e) Other acronyms and abbreviations. This part uses the following additional abbreviations and acronyms:

A/C	air conditioning
ALVW	adjusted loaded vehicle weight
CFR	Code of Federal Regulations
CFV	critical-flow venturi
CVS	constant-volume sampler
EPA	Environmental Protection Agency
ETW	equivalent test weight
EV	electric vehicle
FID	flame-ionization detector
FTP	Federal test procedure
GC	gas chromatograph
GHG	greenhouse gas (including CO_2, N_2O, and CH_4)
GVWR	gross vehicle weight rating
HEV	hybrid electric vehicle
HFET	highway fuel economy test
HLDT	heavy light-duty truck
HPLC	high pressure liquid chromatography
IBR	incorporated by reference
MDPV	medium-duty passenger vehicle
NIST	National Institute for Standards and Technology

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PDP	positive-displacement pump
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
RESS	rechargeable energy storage system
SAE	Society of Automotive Engineers
SC03	air conditioning driving schedule
SEA	selective enforcement audit
SFTP	supplemental federal test procedure
SSV	subsonic venturi
UDDS	urban dynamometer driving cycle
US06	aggressive driving schedule
U.S.C.	United States Code

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(f) This part uses the following densities of chemical species:

Symbol	Quantity[1,2]	g/m^3	g/ft^3
ρ_{CH4}	density of methane	666.905	18.8847
ρ_{CH3OH}	density of methanol	1332.02	37.7185
ρ_{C2H5OH}	C_1-equivalent density of ethanol	957.559	27.1151
ρ_{C2H4O}	C_1-equivalent density of acetaldehyde	915.658	25.9285
ρ_{C3H8}	density of propane	611.035	17.3026
ρ_{C3H7OH}	C_1-equivalent density of propanol	832.74	23.5806
ρ_{CO}	density of carbon monoxide	1164.41	32.9725
ρ_{CO2}	density of carbon dioxide	1829.53	51.8064
$\rho_{HC\text{-}gas}$	effective density of hydrocarbon - gaseous fuel[3]	(see 3)	(see 3)
ρ_{HCHO}	density of formaldehyde	1248.21	35.3455
$\rho_{HC\text{-}liq}$	effective density of hydrocarbon - liquid fuel[4]	576.816	16.3336
$\rho_{NMHC\text{-}gas}$	effective density of nonmethane hydrocarbon - gaseous fuel[3]	(see 3)	(see 3)
$\rho_{NMHC\text{-}liq}$	effective density of nonmethane hydrocarbon - liquid fuel[4]	576.816	16.3336
$\rho_{NMHCE\text{-}gas}$	effective density of nonmethane equivalent hydrocarbon - gaseous fuel[3]	(see 3)	(see 3)
$\rho_{NMHCE\text{-}liq}$	effective density of nonmethane equivalent hydrocarbon - liquid fuel[4]	576.816	16.3336
ρ_{NOx}	effective density of oxides of nitrogen[5]	1912.5	54.156
ρ_{N2O}	density of nitrous oxide	1829.66	51.8103

[1]Densities are given at 20 °C and 101.325 kPa.
[2]Densities for all hydrocarbon containing quantities are given in kg/m^3-carbon atom and g/ft^3-carbon atom.
[3]The effective density for natural gas fuel and liquefied petroleum gas fuel are defined by an atomic hydrogen-to-carbon ratio, α, of the hydrocarbon components of the test fuel. $\rho_{HCgas} = 0.04157 \cdot (12.011 + (\alpha \cdot 1.008))$.
[4]The effective density for gasoline and diesel fuel are defined by an atomic hydrogen-to-carbon ratio, α, of 1.85.
[5]The effective density of NO_x is defined by the molar mass of nitrogen dioxide, NO_2.

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(g) Constants. (1) This part uses the following constants for the composition of dry air:

Symbol	Quantity	mol/mol
x_{Arair}	amount of argon in dry air	0.00934
x_{CO2air}	amount of carbon dioxide in dry air	0.000375

x_{N2air}	amount of nitrogen in dry air	0.78084
x_{O2air}	amount of oxygen in dry air	0.209445

(2) This part uses the following molar masses or effective molar masses of chemical species:

Symbol	Quantity	g/mol ($10^{-3}\cdot kg\cdot mol^{-1}$)
M_{air}	molar mass of dry air[1]	28.96559
M_{H2O}	molar mass of water	18.01528

[1]See paragraph (g)(1) of this section for the composition of dry air.

§1066.1010 Reference materials.

(a) Certain material is incorporated by reference into this part with the approval of the Director of the Federal Register under 5 U.S.C. 552(a) and 1 CFR part 51. To enforce any edition other than that specified in this section, the Environmental Protection Agency must publish a notice of the change in the *Federal Register* and the material must be available to the public. All approved material is available for inspection at U.S. EPA, Air and Radiation Docket and Information Center, 1301 Constitution Ave., NW., Room B102, EPA West Building, Washington, DC 20460, (202) 202-1744, and is available from the sources listed below. It is also available for inspection at the National Archives and Records Administration (NARA). For information on the availability of this material at NARA, call 202–741–6030, or go to http://www.archives.gov/federal_register/code_of_federal_regulations/ibr_locations.html.

(b) Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096–0001, (877) 606–7323 (U.S. and Canada) or (724) 776–4970 (outside the U.S. and Canada), http://www.sae.org.

(1) SAE J1263, Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques, Revised March 2010, IBR approved for §§1066.301(b) and 1066.310(b).

(2) SAE J1634, Electric Vehicle Energy Consumption and Range Test Procedure, Revised October 2012, IBR approved for §1066.501.

(3) SAE J1711, Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-In Hybrid Vehicles, Revised June 2010, IBR approved for §§1066.122 and 1066.501.

(4) SAE J2263, Road Load Measurement Using Onboard Anemometry and Coastdown Techniques, Revised December 2008, IBR approved for §§1066.301(b) and 1066.310(b).

(5) SAE J2264, Chassis Dynamometer Simulation of Road Load Using Coastdown Techniques, Issued April 1995, IBR approved for §1066.320.

(6) SAE J2711, Recommended Practice for Measuring Fuel Economy and Emissions of Hybrid-Electric and Conventional Heavy-Duty Vehicles, Issued September 2002, IBR approved for §1066.501.

(7) SAE J2951, Drive Quality Evaluation for Chassis Dynamometer Testing, Revised November 2011, IBR approved for §1066.430.

(c) National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, (301) 975-6478, www.nist.gov, or inquiries@nist.gov.

(1) NIST Special Publication 811, 2008 Edition, Guide for the Use of the International System of Units (SI), March 2008, IBR approved for §§1066.20(a) and 1066.1005.

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(f) Verify the amount of nonmethane hydrocarbon (or equivalent) contamination in the exhaust and background HC sampling systems within 8 hours before the start of the first test drive cycle for each individual vehicle tested as described in 40 CFR 1065.520(g).

§1066.425 Engine starting and restarting.

(a) Start the vehicle's engine as follows:

(1) At the beginning of the test cycle, start the engine according to the procedure you describe in your owners manual. In the case of hybrid vehicles, this would generally involve activating vehicle systems such that the engine will start when the vehicle's control algorithms determine that the engine should provide power instead of or in addition to power from the rechargeable energy storage system (RESS). Unless we specify otherwise, engine starting throughout this part generally refers to this step of activating the system on hybrid vehicles, whether or not that causes the engine to start running.

(2) Place the transmission in gear as described by the test cycle in the standard-setting part. During idle operation, you may apply the brakes if necessary to keep the drive wheels from turning.

(b) If the vehicle does not start after your recommended maximum cranking time, wait and restart cranking according to your recommended practice. If you don't recommend such a cranking procedure, stop cranking after 10 seconds, wait for 10 seconds, then start cranking gain for up to 10 seconds. You may repeat this for up to three start attempts. If the vehicle does not start after three attempts, you must determine and record the reason for failure to start. Shut off sampling systems and either turn the CVS off, or disconnect the exhaust tube from the tailpipe during the diagnostic period. Reschedule the vehicle for testing from a cold start.

(c) Repeat the recommended starting procedure if the engine has a "false start".

(d) Take the following steps if the engine stalls:

(1) If the engine stalls during an idle period, restart the engine immediately and continue the test. If you cannot restart the engine soon enough to allow the vehicle to follow the next acceleration, stop the driving schedule indicator and reactivate it when the vehicle restarts.

(2) If the engine stalls during operation other than idle, stop the driving schedule indicator, restart the engine, accelerate to the speed required at that point in the driving schedule, reactivate the driving schedule indicator, and continue the test.

(3) Void the test if the vehicle will not restart within one minute. If this happens, remove the vehicle from the dynamometer, take corrective action, and reschedule the vehicle for testing. Record the reason for the malfunction (if determined) and any corrective action. See the standard-setting part for instructions about reporting these malfunctions.

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The overall test consists of prescribed sequences of fueling, parking, and driving at specified test conditions.

(a) Vehicles are tested for criteria pollutants and greenhouse gas emissions as described in the standard-setting part.

(b) Take the following steps before emission sampling begins:

(1) For batch sampling, connect clean storage media, such as evacuated bags or tare-weighed filters.

(2) Start all measurement instruments according to the instrument manufacturer's instructions and using good engineering judgment.

(3) Start dilution systems, sample pumps, and the data-collection system.
(4) Pre-heat or pre-cool heat exchangers in the sampling system to within their operating temperature tolerances for a test.
(5) Allow heated or cooled components such as sample lines, filters, chillers, and pumps to stabilize at their operating temperatures.
(6) Verify that there are no significant vacuum-side leaks according to 40 CFR 1065.345.
(7) Adjust the sample flow rates to desired levels using bypass flow, if desired.
(8) Zero or re-zero any electronic integrating devices before the start of any test interval.
(9) Select gas analyzer ranges. You may automatically or manually switch gas analyzer ranges during a test only if switching is performed by changing the span over which the digital resolution of the instrument is applied. During a test you may not switch the gains of an analyzer's analog operational amplifier(s).
(10) Zero and span all continuous gas analyzers using NIST-traceable gases that meet the specifications of 40 CFR 1065.750. Span FID analyzers on a carbon number basis of one (C_1). For example, if you use a C_3H_8 span gas of concentration 200 μmol/mol, span the FID to respond with a value of 600 μmol/mol. Span FID analyzers consistent with the determination of their respective response factors, *RF*, and penetration fractions, *PF*, according to 40 CFR 1065.365.
(11) We recommend that you verify gas analyzer responses after zeroing and spanning by sampling a calibration gas that has a concentration near one-half of the span gas concentration. Based on the results and good engineering judgment, you may decide whether or not to re-zero, re-span, or re-calibrate a gas analyzer before starting a test.
(12) If you correct for dilution air background concentrations of associated engine exhaust constituents, start sampling and recording background concentrations.
(13) Turn on cooling fans immediately before starting the test.
(c) Operate vehicles during testing as follows:
(1) Where we do not give specific instructions, operate the vehicle according to your recommendations in the owners manual, unless those recommendations are unrepresentative of what may reasonably be expected for in-use operation.
(2) If vehicles have features that preclude dynamometer testing, modify these features as necessary to allow testing, consistent with good engineering judgment.
(3) Operate vehicles during idle as follows:
(i) For a vehicle with an automatic transmission, operate at idle with the transmission in "Drive" with the wheels braked, except that you may shift to "Neutral" for the first idle period and for any idle period longer than one minute. If you put the vehicle in "Neutral" during an idle, you must shift the vehicle into "Drive" with the wheels braked at least 5 seconds before the end of the idle period.
(ii) For vehicles with manual transmission, operate at idle with the transmission in gear with the clutch disengaged, except that you may shift to "Neutral" with the clutch disengaged for the first idle period and for any idle period longer than one minute. If you put the vehicle in "Neutral" during idle, you must shift to first gear with the clutch disengaged at least 5 seconds before the end of the idle period.
(4) Operate the vehicle with the appropriate accelerator pedal movement necessary to achieve the speed versus time relationship prescribed by the driving schedule. Avoid smoothing speed variations and excessive accelerator pedal perturbations.
(5) Operate the vehicle smoothly, following representative shift speeds and procedures. For manual transmissions, the operator shall release the accelerator pedal during each shift and

accomplish the shift with minimum time. If the vehicle cannot accelerate at the specified rate, operate it at maximum available power until the vehicle speed reaches the value prescribed for that time in the driving schedule.
(6) Decelerate without changing gears, using the brakes or accelerator pedal as necessary to maintain the desired speed. Keep the clutch engaged on manual transmission vehicles and do not change gears after the end of the acceleration event. Depress manual transmission clutches when the speed drops below 6.7 m/s (15 mph), when engine roughness is evident, or when engine stalling is imminent.
(7) For test vehicles equipped with manual transmissions, shift gears in a way that represents reasonable shift patterns for in-use operation, considering vehicle speed, engine speed, and any other relevant variables. You may recommend a shift schedule in your owners manual that differs from your shift schedule during testing as long as you include both shift schedules in your application for certification. In this case, we may use the shift schedule you describe in your owners manual.

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mass of

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Calculate the mass of particulate matter emission

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Calculate the mass of particulate matter emission

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If you sample PM onto a single filter per test phase as described in §1066.822(c) or onto a single filter per UDDS test phase as described in §1066.820(b)(3) or

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phase

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phase

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V_{gasstd} = total volume of sample flow through the gaseous emission bench over the test phase at standard temperature and pressure.
V_{PMstd} = total volume of dilute exhaust sampled

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through the filter over the test phase at standard temperature and pressure.

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V_{mixstd} = total dilute exhaust volume over the test phase at the flow meter at standard reference conditions of 293.15 K and 101.3 kPa.

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V_{mixstd} = 170.492 m^3, where V_{mixact} = 170.72 m^3, p_B = 101.7 kPa, p_{in} = 0 kPa, and T_{in} = 294.7 K
Using

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V_{gasstd} = 0.0291 m^3, where V_{gasact} = 0.0337 m^3, p_B = 101.7 kPa, p_{in} = 0 kPa, and T_{in} = 340.5 K
Using

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V_{PMstd} = 0.9248 m^3, where V_{PMact} = 1.07 m^3, p_B = 101.7 kPa, p_{in} = 0 kPa, and T_{in} = 340.5 K
Using

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V_{sdastd} = 0.527 m^3, where V_{sdaact} = 0.531 m^3, p_B = 101.7 kPa, p_{in} = 0 kPa, and T_{in} = 296.3 K
V_{mix} = 170.492 + 0.0291 + 0.9248 – 0.527 = 170.919 m^3

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for all test phases

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for all test phases

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(2) For the SC03 test cycle, use the following equation to correct measured concentrations to a reference condition of 10.71 of H_2O vapor per kilogram of dry air:

$$x_{NOxdexhcor} = x_{NOxdexh} \cdot \frac{0.8825}{1 - 0.0329 \cdot (H - 10.71)}$$

Eq. 1066.630-3

Where:
H = Absolute humidity in grams of H_2O vapor per kilogram of dry air according to Eq. 1066.630-2.

Example:
RH = 55.9 %
P_d = 2.93 kPa
P_B = 96.71 kPa
H = 10.7148 g H_2O vapor/kg dry air
$x_{NOxdexh}$ = 1.2 ppm

$$x_{NOxdexhcor} = 1.2 \cdot \frac{0.8825}{1 - 0.0329 \cdot (10.7148 - 10.71)} = 1.059 \text{ ppm}$$

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calibration equations on a molar basis; however, 40 CFR 1065.640(a) allows for conversion between volumetric and molar flow rate. If you are using mass-based emission calculations to determine your total mass of emissions over a test cycle, you may calibrate your flow meters volumetrically using Equation 1065.640-1 to convert the molar flow calibration equations throughout all of 40 CFR 1065.640 to volumetric flow equations

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After you calibrate a flow meter using these calculations, use the calculations described in §1066.652 to calculate flow during an emission test.

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For each restrictor position, calculate the following values from the mean values determined in §1066.140, as follows:

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$\bar{f}_{nPDP}$ = 1205.1 r/min = 20.085 r/s

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m_{OHCi} = the C_1-equivalent mass of oxygenated species i in the exhaust calculated using Eq. 1066.610-1 and the density of the oxygenated species i as given in §1066.1005(f).

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m_{OHCi} = the C_1-equivalent mass of oxygenated species i in the exhaust calculated using Eq. 1066.610-1 and the density of the oxygenated species i as given in §1066.1005(f).

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m_{OHCi} = the C_1-equivalent mass of oxygenated species *i* in the exhaust calculated using Eq. 1066.610-1 and the density of the oxygenated species *i* as given in §1066.1005(f).

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m_{OHCi} = the C_1-equivalent mass of oxygenated species *i* in the exhaust calculated using Eq. 1066.610-1 and the density of the oxygenated species *i* as given in §1066.1005(f).

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You may generate your own response factors or use the following response factors, consistent with good engineering judgment:

Table 1 of §1066.665–Default values for THC FID response factor relative to propane on a C_1-equivalent basis

Compound	Response factor (*RF*)
methanol	0.63
ethanol	0.75
propanol	0.85
formaldehyde	0.00
acetaldehyde	0.50

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RL	road-load coefficient	horsepower or kilowatt	hp or kW	$10^3 \cdot m^2 \cdot kg \cdot s^{-3}$

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S	speed	miles per hour or meters per second	mph or m/s	$m \cdot s^{-1}$

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NONMHC	nonoxygenated nonmethane hydrocarbon

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int	speed interval

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final	final

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si	speed interval