(f) *SAE material.* Copies of these materials may be obtained from the Society of Automotive Engineers International, 400 Commonwealth Dr., Warrendale, PA 15096–0001, or by calling (724) 776–4841, or at *http://www.sae.org.*

(1) SAE 770141, 2001, Optimization of Flame Ionization Detector for Determination of Hydrocarbon in Diluted Automotive Exhausts, Glenn D. Reschke, IBR approved for § 1065.360.

(2) [Reserved]

[77 FR 2464, Jan. 18, 2012]

PART 1066—VEHICLE-TESTING PROCEDURES

Subpart A—Applicability and General Provisions

Subpart B—Equipment, Fuel, and Gas Specifications

Subpart C—Dynamometer Specifications

Subpart D—Coastdown

Subpart E—Vehicle Preparation and Running a Test

Subpart F—Hybrids

Subpart G—Calculations

Subpart H—Definitions and Other Reference Material

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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) [Reserved]

(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.

(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 *http://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, field 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.

(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 is 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. We may approve your request to omit measurement of N_2O and CH_4 for a vehicle, provided it is not subject to an N_2O or CH_4 emission standard and we determine that other information is available to give us a reasonable basis for estimating or approximating the vehicle's emission rates.

(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) Is field testing required or allowed, and are there different emission standards or procedures that apply to field testing?

(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:

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	Definitions and reference material.

§ 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 for laboratory testing, field testing, or both, 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.

§ 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:

(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.

(3) Particulate mass, PM.

(4) Carbon monoxide, CO.

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

(c) We generally set emission standards over test intervals and/or drive schedules, as follows:

(1) *Vehicle operation*. Testing may involve measuring emissions and miles travelled in a laboratory-type environment or in the field. The standard-setting part specifies how test intervals are defined for field testing. Refer to the definitions of ''duty cycle'' and ''test interval'' in § 1066.701. Note that a single drive schedule may have multiple test intervals and require weighting of results from multiple test phases to calculate a composite distance-based emission value to compare to the standard.

(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 phase. 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.

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

§ 1066.20 Units of measure and overview of calculations.

(a) *System of units*. The procedures in this part follows both conventional English Units and the International System of Units (SI), as detailed in NIST Special Publication 811, which we incorporate by reference in § 1066.710.

(b) *Units conversion.* Use good engineering judgment to convert units between measurement systems as needed. 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.

(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, target any associated control point to that single value. Examples of this type of range include ''±10% of maximum pressure'', or ''(30 ±10) kPa''.

(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. Refer to 40 CFR 1065.602 for information needed to estimate and calculate flow-weighted means.

§ 1066.25 Recordkeeping.

The procedures in this part include various requirements to record data or other information. Refer to the standard-setting part regarding recordkeeping requirements. If the standard-setting part does not specify recordkeeping requirements, store these records in any format and on any media and keep them readily available for one year after you send an associated application for certification, or one year after you generate the data if they do not support an application for certification. You must promptly send us organized, written records in English if we ask for them. We may review them at any time.

Subpart B—Equipment, Fuel, and 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 1065.140 through 1065.195 specify equipment for exhaust dilution and sampling systems.

(2) The provisions of 40 CFR part 1065, subparts C and D, specify measurement instruments and their calibrations.

(3) The provisions of 40 CFR part 1065, subpart H, specify fuels, engine fluids, and analytical gases.

(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.

(c) The provisions of this subpart are intended to specify systems that can very accurately and precisely measure emissions from motor vehicles. We may waive or modify the specifications and requirements of this part for testing highway motorcycles or nonroad 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.

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 intermediate 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 to a resolution of ±0.05% of the maximum forces simulated by the dynamometer or ±0.9 N (±0.2 lbf), whichever is greater, during a test.

(c) *Test cycles.* The dynamometer must be capable of fully simulating applicable test cycles for the vehicles being tested as referenced in the corresponding standard-setting part.

(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.

(d) *Component requirements.* The dynamometer must meet the following specifications:

(1) For vehicles with GVWR at or below 14,000 lbs, the nominal roll diameter must be 1.20 to 1.25 meters. The dynamometer must have an independent drive roll for each axle being driven by the vehicle during an emission test.

(2) For vehicles with GVWR above 14,000 lbs, the nominal roll diameter must be at least 1.20 meters and no greater than 3.10 meters. The dynamometer must have an independent drive roll for each axle, 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.

(3) If you measure force and speed at 10 Hz or faster, you may use good engineering judgment to convert those measurements to 1-Hz, 2-Hz, or 5-Hz values.

(4) The load applied by the dynamometer simulates forces acting on the vehicle during normal driving according to the following equation:

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

Eq. 1066.210-1

Where:

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* is 6,000.

A = constant value representing the vehicle's frictional load in lbf or newtons. See subpart C 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 C of this part.

S = linear speed at the roll surfaces as measured by the dynamometer, in mph or m/s. Let $S_{i\text{-}1} = 0$.

C = coefficient representing aerodynamic effects, which are a function of vehicle speed squared, in lbf/mph² or N·s²/m². See subpart C of this part.

M = mass of vehicle in lbm or kg. 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 $t_{i\text{-}1} = 0$.

(5) The dynamometer must be designed to generally 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.

(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.

§ 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, within 370 days before testing, and after major maintenance.
§ 1066.225: Roll runout and diameter	Upon initial installation and after major maintenance.
§ 1066.230: Time	Upon initial installation and after major maintenance.
§ 1066.235: Speed measurement	Upon initial installation, within 370 days before testing, and after major maintenance.
§ 1066.240: Torque (load) transducer	Upon initial installation and after major maintenance.
§ 1066.245: Response time	Upon initial installation and after major maintenance.
§ 1066.250: Base inertia	Upon initial installation and after major maintenance.
§ 1066.255: Parasitic loss	Upon initial installation, within 7 days before testing, and after major maintenance.
§ 1066.260: Parasitic friction compensation evaluation.	Upon initial installation, within 7 days before testing, and after major maintenance.

TABLE 1 OF § 1066.215—SUMMARY OF REQUIRED DYNAMOMETER CALIBRATIONS AND VERIFICATIONS—Continued

Type of calibration or verification	Minimum frequency [a]
§ 1066.265: Acceleration and deceleration	Upon initial installation and after major maintenance.
§ 1066.270: Unloaded coastdown	Upon initial installation, within 7 days 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. At other times, you may need to perform specific verifications or calibration in a certain sequence, as noted in this subpart.

(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.

(a) *Scope and frequency*. Perform linearity verifications upon initial installation, within 370 days before testing, and after major maintenance. Note that these linearity verifications may replace requirements previously referred to as calibrations. The intent of linearity verification is to determine that a measurement 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 (or the manufacturer's recommend number of 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.

(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 a dynamometer system at the specified temperatures and pressures. This may include any specified adjustment or periodic calibration of the dynamometer system.

(3) Set dynamometer speed and torque to zero and apply the dynamometer brake to ensure a zero-speed condition.

(4) Span the dynamometer speed or torque signal.

(5) After spanning, check for zero speed and torque. Use good engineering

judgment to determine whether or not to rezero or re-span before continuing.

(6) For both speed and torque, use the dynamometer manufacturer's recommendations and good engineering judgment to select reference values, $y_{\mathrm{ref}i}$, 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 or 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 conditions.

(12) Use the arithmetic means, $\bar{y}_i$, and reference values, $y_{\mathrm{ref}i}$, 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.*, ($y_{\mathrm{ref}i}$, $\bar{y}_i$)), in the linear regression calculations.

TABLE 1 OF § 1066.220—DYNAMOMETER MEASUREMENT SYSTEMS THAT REQUIRE LINEARITY VERIFICATIONS

Measurement system	Quantity	Linearity criteria $\lvert x_{\min}(a_1-1)+a_0 \rvert$	a_1	*SEE*	r^2
Speed	*S*	≤0.05% · $S_{\max}$	0.98–1.02	≤2% · $S_{\max}$	≥0.990
Torque (load)	*T*	≤1% · $T_{\max}$	0.98–1.02	≤2% · $T_{\max}$	≥0.990

§ 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.

(c) *Roll runout procedure*. Verify roll runout as follows:

(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 a dial 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 dial indicator must have a magnetic base assembly or other means of being securely mounted adjacent to the roll. The dial indicator must have sufficient range to measure roll runout at

all points, with a minimum accuracy and precision of ±0.025 mm. Calibrate the dial indicator according to the instrument manufacturer's instructions.

(3) Position the dial indicator adjacent to the roll surface at the desired measurement location. Position the shaft of the dial indicator perpendicular to the roll such that the point of the dial indicator is slightly touching the surface of the roll and can move freely through a full rotation of the roll. Zero the dial 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 dial 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 0.25 mm 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.

(5) The measured roll diameter must be within ±0.25 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:

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

Eq. 1066.230-1

(2) *Ramping method.* You may set up an operator-defined ramp function in the signal generator 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 Equation 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 Equation 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.

(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 between 4.2 m/s and the maximum speed expected during testing; record the output of the frequency counter after 10 seconds. Determine the roll speed, S_{act}, using the following equation:

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

Eq. 1066.235-1

Where:

f = frequency of the dynamometer speed sensing device, in s^{-1}, accurate to at least four significant figures.

d_{roll} = nominal roll diameter, in m, accurate to the nearest 0.01 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

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

S_{act} = 8.3053 m/s

(ii) Compare the calculated roll speed, $S_{act,}$ to the corresponding speed set point, $S_{ref,}$ to determine a value for speed error, $S_{error,}$ using the following equation:

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

Eq. 1066.235-2

Example:

S_{act} = 8.3053 m/s

S_{ref} = 8.3000 m/s

S_{error} = 8.3053 − 8.3000 = 0.0053 m/s

(2) *Frequency method.* Use the method described in this paragraph (c)(2) only if the dynamometer does not have a readily available output signal for speed sensing. Install a single 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 arrow. 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 value between 15 kph and the maximum speed expected during testing. Tune the stroboscope or photo tachometer until the signal matches the dynamometer roll speed. Record the frequency. Determine the roll speed, $y_{act,}$ using Equation 1066.235–1, using the stroboscope or photo tachometer's frequency for f.

(ii) Compare the calculated roll speed, $y_{act,}$ to the corresponding speed set point, $y_{ref,}$ to determine a value for speed error, $y_{error,}$ using Equation 1066.235–2.

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

§ 1066.240 Torque transducer verification and calibration.

Calibrate torque-measurement systems as described in 40 CFR 1065.310.

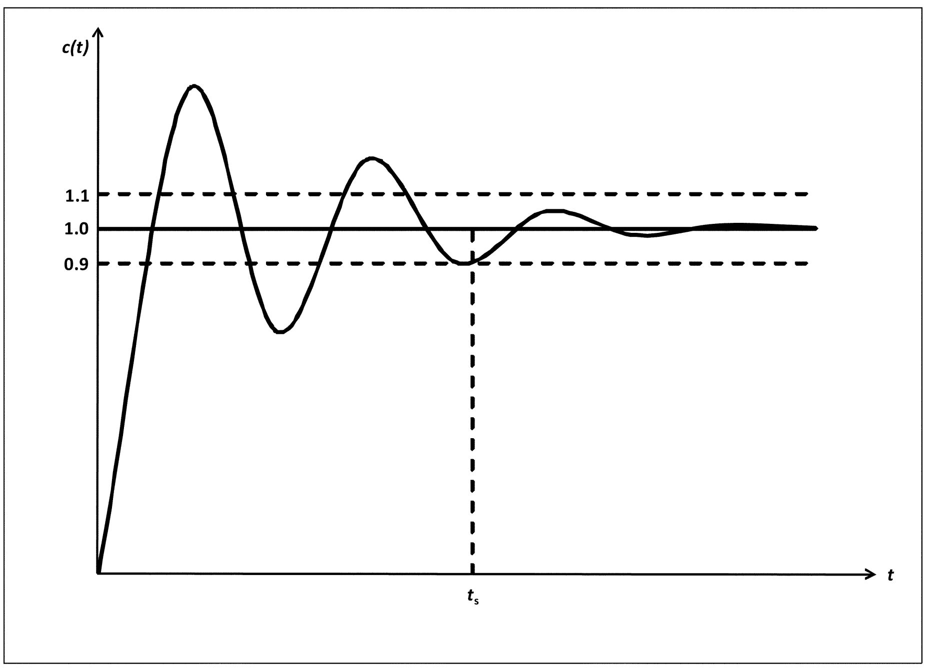
§ 1066.245 Response time verification.

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

(b) *Scope and frequency.* Perform this verification upon initial installation and after major maintenance.

(c) *Procedure.* Use the dynamometer's automated process to verify response time. Perform this test at two different inertia settings corresponding approximately to the minimum and maximum vehicle weights you expect to test. 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.

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.

(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 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:

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

Eq. 1066.250-1

Where:

F = average dynamometer force over the measurement interval as measured by the dynamometer, in ft·lbm/s^2.

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

$S_{initial}$ = 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

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

$S_{initial}$ = 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) Determine the arithmetic mean value of base inertia from the five measurements at each acceleration and deceleration rate. Calculate these six mean values as described in 40 CFR 1065.602(b).

(7) Calculate the base inertia error, I_{berror}, for each measured base inertia, 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

$\bar{I}_{bact}$ = 33.01 lbm

$$I_{\text{berror}} = \frac{32.96 - 33.01}{32.96} \cdot 100\,\%$$

$I_{\text{berror}} = -0.15\%$

(8) Calculate the inertia error for each mean value of base inertia from paragraph (c)(6) of this section. Use Equation 1066.265–2, substituting the mean base inertias associated with each acceleration and deceleration rate for the individual base inertias.

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

(1) The base inertia error determined under paragraph (c)(7) of this section may not exceed ±0.50% relative to any individual value.

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

§ 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, within 7 days of testing, and after major maintenance.

(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 the 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 ±4.5 N (±1.0 lbf).

§ 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, within 7 days before testing, and after major maintenance. Note that this procedure relies on proper verification or calibration of speed and torque, as described in §§ 1066.235 and1066.240. 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.

(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 10 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 friction compensation error, FC_{error}, using the following equation:

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

Eq. 1066.260-1

Where:

I = dynamometer inertia setting, in lbf·s²/ft.

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

S_{final} = the roll speed corresponding to the end of the measurement interval, accurate to at least 0.1 mph.

S_{init} = the roll speed corresponding to the start of the measurement interval, accurate to at least 0.1 mph.

Example:

I = 2000 lbm = 62.16 lbf· s²/ft

t = 60.0 s

S_{final} = 9.2 mph = 13.5 ft/s

S_{init} = 10.0 mph = 14.7 ft/s

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

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

(5) The friction compensation error may not exceed ±0.1 hp.

§ 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 upon initial installation and after major maintenance.

(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 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:

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

Eq. 1066.265-1

Where:

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

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:

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

Eq. 1066.265-2

Where:

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

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

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

t = time to accelerate from S_{init} to $S_{final.}$

Example:

S_{inal} = 40 mph

S_{init} = 10 mph

t = 30.003 s

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

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 Equation 1066.265–2.

(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, $\bar{a}_{act}$, at each setting.

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

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

Eq. 1066.265-3

Example:

$\bar{a}_{act}$ = 0.999 mph/s
a_{ref} = 1 mph/s
a_{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

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

Eq. 1066.265-4

Where:

I_b = the dynamometer manufacturer's stated base inertia, in lbf·s²/ft.
a = nominal acceleration rate, in ft/s².

Example:

I_b = 2967 lbm = 92.217 lbf·s²/ft
a = 1 mph/s = 1.4667 ft/s²
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 Equation 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, $\bar{a}_{act}$, 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.

(4) Compare each mean acceleration rate, $\bar{a}_{act}$, to the corresponding nominal acceleration rate, $a_{ref,}$ to determine values for acceleration error, $a_{error,}$ using Equation 1066.265–4.

(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 and final speed and the inertial 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 operate at 10 mph. Perform a coastdown two times at this speed setting. Repeat these coastdown steps in 10 mph increments up to and including one increment above the maximum speed expected during testing. You may stop the verification before reaching 0 mph, with any appropriate adjustments in calculating the results.

(3) Repeat the steps in paragraph (c)(2) of this section with the dynamometer inertia set for the largest vehicle weight that you expect to test.

(4) Determine the average coastdown force, F, for each speed and inertia setting using the following equation:

$$F = \frac{I \cdot S_{si}}{t}$$

Eq. 1066.270-1

Where:

F = the average force measured during the coastdown for each speed and inertia setting, expressed in lbf·s²/ft and rounded to four significant figures.

I = the dynamometer's inertia setting, in lbf·s²/ft.

S_{si} = the speed setting at the start of the coastdown, expressed in ft/s and 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·s²/ft

S_{si} = 10 mph = 14.66 ft/s

t = 5.00 s

$$F = \frac{65.17 \cdot 14.66}{5.00}$$

F = 191 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:

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

Eq. 1066.270-2

Example:
F_{ref} = 192 lbf
$\bar{F}_{act}$ = 191 lbf

$$F_{error} = \frac{191 - 192}{192} \cdot 100\ \%$$

$F_{error} = -0.5\%$

(7) The maximum allowable error, $F_{errormax}$, for all speed and inertia settings is calculated from the following formula, except that $F_{errormax}$ for vehicles with GVWR above 14,000 lbs may be up to ±1.0%:

$F_{errormax}\ (\%) = (2.2\ \text{lbf}/F_{ref}) \cdot 100$

§ 1066.280 Driver's aid.

Use good engineering judgment to provide a driver's aid that facilitates compliance with the requirements of § 1066.430.

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 § 1066.710). 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.

§ 1066.310 Coastdown procedures for heavy-duty vehicles.

This section describes coastdown procedures that are unique to heavy-duty motor vehicles. Note as specified in the standard setting parts, this section does not apply for certain heavy-duty vehicles, such as those regulated under 40 CFR part 86, subpart S.

(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 § 1066.710), 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 in the analysis. To calculate the force due to grade use Section 11.5 of SAE J2263.

(2) You must reach a top speed of greater than 70 mph such that data collection of the coastdown can start at or above 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 of 70 mph 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) Run the zero-wind and zero-angle calibration data collection.

(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.

(iii) 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.

(iv) 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.

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

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

(vii) 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 each direction.

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

(i) 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.

(ii) 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.

(iii) Calculate the road-load force for each measurement interval, F_i, using the following equation:

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

Eq. 1066.310-1

Where:

v = Vehicle speed at the beginning and end of the measurement interval. Let v_0 = 0.

Δt = Elapsed time over the measurement interval.

(iv) 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 Δh = 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.

(v) 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:

A = A_m
B = 0
C = D_{adj}

Subpart E—Vehicle Preparation and Running a Test

§ 1066.401 Overview.

(a) Use the procedures detailed in this subpart to measure vehicle emissions over a specified drive schedule. 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) An 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 86, subpart B, or 40 CFR part 1065, subpart G, 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.

This section describes steps to take before measuring exhaust emissions for those vehicles that are subject to evaporative or refueling emission tests as specified in the standard setting part. Other preliminary procedures may apply as specified in the standard-setting part.

(a) Prepare the vehicle for testing as described in 40 CFR 86.131.

(b) If testing will include measurement of refueling emissions, perform the vehicle preconditioning steps as described in 40 CFR 86.153. Otherwise, perform the vehicle preconditioning steps as described in 40 CFR 86.132.

§ 1066.410 Dynamometer test procedure.

(a) Dynamometer testing may consist of multiple drive cycles with both cold-start and hot-start portions, including prescribed soak times before each test phase. See the standard-setting part for test cycles and soak times for the appropriate vehicle category. A test phase consists of engine startup (with accessories operated according to the standard-setting part), operation over the drive cycle, and engine shutdown.

(b) During dynamometer operation, position a cooling fan that appropriately directs cooling air to the vehicle. This generally requires squarely positioning the fan within 30 centimeters of the front of the vehicle and directing the airflow to the vehicle's radiator.

(1) For vehicles with GVWR at or below 14,000 lbs, you may use either of the following cooling fan configurations:

(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. 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.

(ii) 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. The fan must provide no cooling air for vehicle speeds below 5 mph, unless we approve your request to provide cooling during low-speed operation based on a demonstration that this is appropriate to simulate cooling for in-use vehicles. We recommend that the cooling fan have a minimum opening of 0.2 m^2 and a minimum width of 0.8 m.

(2) For vehicles with GVWR above 14,000 lbs, 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. The fan must provide no cooling air for vehicle speeds below 5 mph, unless we approve your request to provide cooling during low-speed operation based on a demonstration that this is appropriate to simulate the cooling experienced by in-use vehicles. 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.

(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 m/s or 0.1 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. You may not measure emissions during a practice run.

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

(f) For vehicles with GVWR above 14,000 lbs, you must use a vehicle pull down mechanism that allows simulation of the actual normal forces that the tire and dynamometer roll interface would see if a loaded vehicle were actually being tested. Use of this mechanism will ensure that wheel slip does not occur when trying to accelerate the loaded vehicle.

(g) Use good engineering judgment when testing vehicles in four-wheel drive or all-wheel drive mode. This may involve testing on a dynamometer with a separate dynamometer roll for each drive axle. This may also involve operation on a single roll, which may require disengaging the second set of drive wheels, either with a switch available to the driver or by some other means; however, operating such a vehicle on a single roll may occur only if this does not decrease emissions or energy consumption relative to normal in-use operation. Alternatively, for heavy-duty motor vehicles, up to two drive axles may use a single drive roll, as described in § 1066.210(d)(2).

(h) Warm up the dynamometer as recommended by the dynamometer manufacturer.

(i) 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 Pre-test verification procedures and pre-test data collection.

(a) Follow the procedures for PM sample preconditioning and tare weighing as described in 40 CFR 1065.590 if your engine must comply with a PM standard.

(b) 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 (b). For purposes of this paragraph (b), ''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(m) for circumstances under which ambient temperatures must remain within this range during the test.

(2) Atmospheric pressure must be (80.000 to 103.325) kPa. You are not required to verify atmospheric pressure prior to a hot-start test interval for testing that also includes a cold start.

(3) Dilution air conditions must meet the specifications in 40 CFR 1065.140, except in cases where you preheat your CVS before a cold-start test. We recommend verifying dilution air conditions just before starting each test phase.

(c) You may test vehicles at any intake-air humidity.

(d) You may perform a final calibration of proportional-flow control systems, which may include performing practice runs.

(e) 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.

(3) Operate any PM sampling systems at their expected flow rates.

(4) Sample PM for at least 10 min 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.

(7) Proceed with the test sequence described in §1066.430.

(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.

§ 1066.430 Performing emission tests.

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.

(d) See the standard-setting part for drive schedules. These are defined by a smooth trace drawn through the specified speed vs. time sequence.

(e) 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 1.0 m/s (2 mph) higher than the highest point on the trace within 1.0 s of the given point in time.

(2) The lower limit is 1.0 m/s (2 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, except that the upper and lower limits for speed values are ±2.0 m/s (±4 mph).

(4) Void the test if you do not maintain speed values as specified in this paragraph (e)(4). 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 paragraph (c)(5) of this section, do not count the insufficient acceleration as being outside the specified limits.

(f) 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.

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

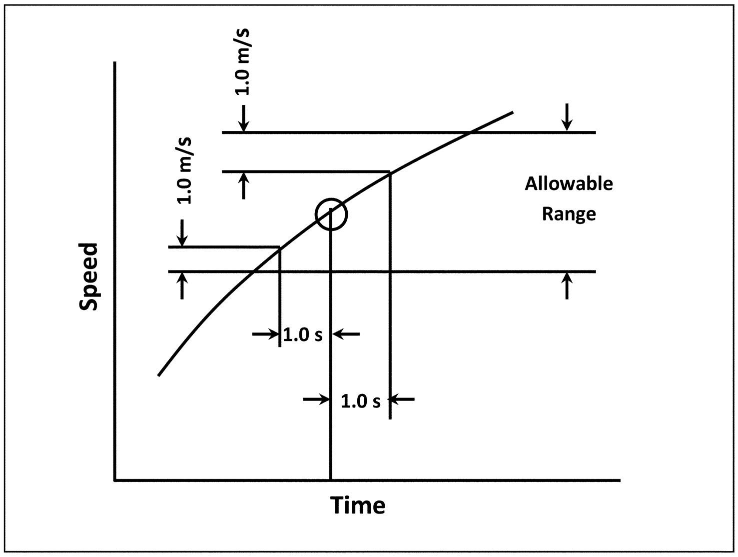
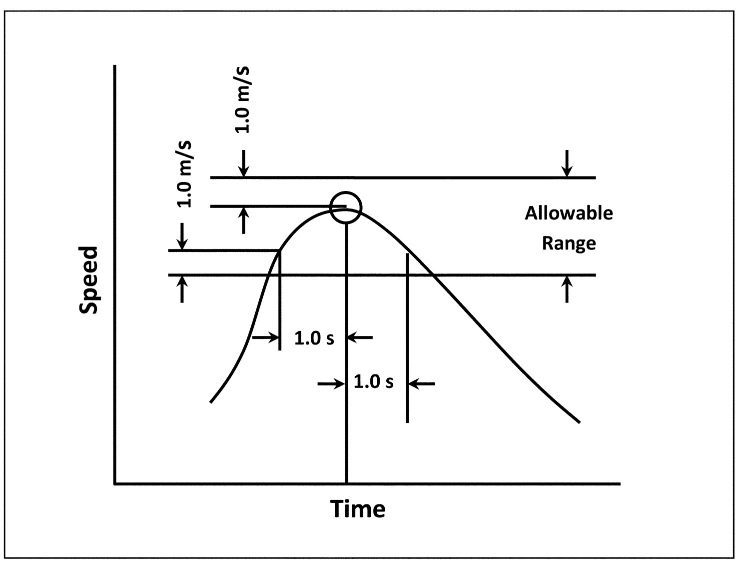


Figure 2 of §1066.430—Example of the allowable ranges for the driver's trace.



(g) 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 phase of the test cycle. Follow the instructions in the standard-setting part to determine how long to stabilize the vehicle during each phase, how long to sample emissions at each phase, and how to transition between phases.

(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.

(h) At the end of each test interval, continue to operate all sampling and dilution systems to allow the response times to elapse. Then stop all sampling and recording, including the recording of background samples. Finally, stop any integrating devices and indicate the end of the duty cycle in the recorded data.

(i) Shut down the vehicle if it is part of the test cycle or if testing is complete.

(j) If testing involves engine shutdown followed by another test phase, start a timer for the vehicle soak when the engine shuts down.

(k) 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 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 test cycle is complete, or optionally during the soak period if practical, perform the following:

(i) Drift check all continuous gas analyzers and zero and span all batch gas analyzers no later than 30 minutes after the test cycle is complete, or during the soak period if practical.

(ii) Analyze any conventional gaseous batch samples no later than 30 minutes after a test phase is complete, or during the soak period if practical. Analyze nonconventional gaseous batch samples, such as NMHCE sampling with ethanol, as soon as practicable using good engineering judgment.

(iii) Analyze background samples no later than 60 minutes after the test cycle is complete.

(4) 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 and correct for drift as described in 40 CFR 1065.550.

(l) [Reserved]

(m) Measure and record ambient temperature and pressure. Also measure humidity, as required, such as for correcting NO_X emissions. For testing vehicles with the following engines, you must record ambient temperature continuously to verify that it remains within the temperature range specified in §1066.420(b)(1) throughout the test:

(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).

Subpart F—Hybrids

§ 1066.501 Overview.

To correct fuel economy or emission results for Net Energy Change of the RESS, use the procedures specified for charge-sustaining operation in SAE J2711 (incorporated by reference in §1066.710).

Subpart G—Calculations

§ 1066.601 Overview.

(a) 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 40 CFR 86.144 or 40 CFR part 1065, subpart G.

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

Subpart H—Definitions and Other Reference Material

§ 1066.701 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.

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 phases.

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 phases into a composite result.

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 S equals $A + B \cdot S + C \cdot S^2$.

Test phase means a duration over which a vehicle's emission rates are determined for comparison to an emission standard. For example, the standard-setting part may specify a complete duty cycle as a cold-start test phase and a hot-start test phase. In cases where multiple test phases occur over a duty cycle, the standard-setting part may specify additional calculations that weight and combine results to arrive at composite values for comparison against the applicable standards.

Test weight has the meaning given in the standard-setting part.

Unloaded coastdown means a dynamometer coastdown run with the vehicle wheels off the roll surface.

§ 1066.705 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 § 1066.710. 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
a	acceleration	feet per second squared or meters per second squared.	ft/s² or m/s²	m·s⁻²

Symbol	Quantity	Unit	Unit symbol	Unit in terms of SI base units
d	diameter	meters	m	m
F	force	pound force or newton	lbf or N	$kg \cdot s^{-2}$
f	frequency	hertz	Hz	s^{-1}
I	inertia	pound mass or kilogram	lbm or kg	kg
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			
R	dynamometer roll revolutions	revolutions per minute	rpm	$2 \cdot \pi \cdot 60^{-1} \cdot m \cdot m^{-1} \cdot s^{-1}$
RL	road-load coefficient	horsepower or kilowatt	hp or kW	$10^3 \cdot m^2 \cdot kg \cdot s^{-3}$
S	speed	miles per hour or meters per second	mph or m/s	$m \cdot s^{-1}$
T	Celsius temperature	degree Celsius	°C	K–273.15
T	torque (moment of force)	newton meter	N·m	$m^2 \cdot kg \cdot s^{-2}$
t	time	second	s	s
Δ*t*	time interval, period, 1/frequency	second	s	s
y	generic variable			

(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
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
N_2O	nitrous oxide
O_2	molecular oxygen
PM	particulate mass
THC	total hydrocarbon
THCE	total hydrocarbon equivalent

(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
int	speed interval
abs	absolute quantity
act	actual or measured condition
actint	actual or measured condition over the speed interval
atmos	atmospheric
b	base
c	coastdown
e	effective
error	error
exp	expected quantity
i	an individual of a series
final	final
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
si	speed interval
span	span quantity
test	test quantity
uncor	uncorrected quantity
zero	zero quantity

(e) *Other acronyms and abbreviations.* This part uses the following additional abbreviations and acronyms:

CFR	Code of Federal Regulations
EPA	Environmental Protection Agency
FID	flame-ionization detector
GVWR	gross vehicle weight rating
NIST	National Institute for Standards and Technology
RESS	rechargeable energy storage system
SAE	Society of Automotive Engineers
U.S.C.	United States Code

§ 1066.710 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 J2263, Road Load Measurement Using Onboard Anemometry and Coastdown Techniques, Revised December 2008, IBR approved for §§1066.301(b), and 1066.310(b).

(3) 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.

(c) National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899–1070, (301) 975–6478, *http://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 1066.705.

(2) [Reserved]

PART 1068—GENERAL COMPLIANCE PROVISIONS FOR HIGHWAY, STATIONARY, AND NONROAD PROGRAMS

Subpart A—Applicability and Miscellaneous Provisions

Sec.

Subpart B—Prohibited Actions and Related Requirements

Subpart C—Exemptions and Exclusions