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OFFICE OF AIR AND RADIATION  
NATIONAL VEHICLE AND FUEL EMISSIONS LABORATORY  
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MEMORANDUM

SUBJECT: Redline Version of EPA's Proposed Regulation to Adopt Greenhouse Gas Emissions Standards for Heavy-Duty Vehicles: Phase 3

FROM: Jessica Brakora, Assessment and Standards Division

TO: Docket EPA-HQ-OAR-2022-0985

EPA is proposing new emission standards for heavy-duty highway vehicles, along with a range of amendments to the emission control program for heavy-duty highway engines and vehicles, as well as other amendments for locomotives, small nonroad spark-ignition engines and equipment, and engine-testing procedures. The attached file is a redline version of the proposed amendments showing the changes relative to the current *Code of Federal Regulations*.

The regulatory text in the attached file is intended to be the same as what will be published in the *Federal Register*. However, there may be some minor differences. The document published in the *Federal Register* is the official copy for purposes of proposal and comment.

Attachment:

- PART 1036— CONTROL OF EMISSIONS FROM NEW AND IN-USE HEAVY-DUTY HIGHWAY ENGINES
- PART 1037— CONTROL OF EMISSIONS FROM NEW HEAVY-DUTY MOTOR VEHICLES
- PART 1054— CONTROL OF EMISSIONS FROM NEW, SMALL NONROAD SPARK-IGNITION ENGINES AND EQUIPMENT
- PART 1065—ENGINE-TESTING PROCEDURES
- PART 1074—PREEMPTION OF STATE STANDARDS AND PROCEDURES FOR WAIVER OF FEDERAL PREEMPTION FOR NONROAD ENGINES AND NONROAD VEHICLES

*The following redline of the proposed regulatory text is intended to reflect what will be published in the Federal Register. However, there may be some minor differences. The document published in the Federal Register is the official copy for purposes of proposal and comment.*

For the reasons set out in the preamble, we are amending title 40, chapter I of the Code of Federal Regulations as set forth below.

## **PART 1036— CONTROL OF EMISSIONS FROM NEW AND IN-USE HEAVY-DUTY HIGHWAY ENGINES**

1. The authority citation for part 1036 continues to read as follows:  
Authority: 42 U.S.C. 7401 - 7671q.

### **Subpart B—Emission Standards and Related Requirements**

2. Amend § 1036.101 by revising the introductory text and paragraph (a)(1) to read as follows:

#### **§ 1036.101 Overview of exhaust emission standards.**

This part contains standards and other regulations applicable to the emission of the air pollutant defined as the aggregate group of six greenhouse gases: carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

(a) \* \* \*

(1) Criteria pollutant standards for NO<sub>x</sub>, HC, PM, and CO apply as described in § 1036.104. These pollutants are sometimes described collectively as “criteria pollutants” because they are either criteria pollutants under the Clean Air Act or precursors to the criteria pollutants ozone and PM.

\* \* \* \* \*

#### **§ 1036.104—[Amended]**

3. Amend § 1036.104 by removing paragraph (c)(2)(iii).
4. Amend § 1036.108 by revising paragraphs (a)(1)(iii) introductory text and (e) to read as follows:

#### **§ 1036.108 Greenhouse gas emission standards—CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O.**

\* \* \* \* \*

(a) \* \* \*

(1) \* \* \*

(iii) The following Phase 2 and Phase 3 CO<sub>2</sub> standards apply for compression-ignition engines and all Heavy HDE (in g/hp·hr):

\* \* \* \* \*

(e) *Applicability for testing.* The emission standards in this subpart apply as specified in this paragraph (e) to all duty-cycle testing (according to the applicable test cycles) of testable configurations, including certification, selective enforcement audits, and in-use testing. The CO<sub>2</sub> FCLs serve as the CO<sub>2</sub> emission standards for the engine family with respect to certification and confirmatory testing instead of the standards specified in paragraph (a)(1) of this section. The FELs serve as the emission standards for the engine family with respect to all other duty-cycle testing. See §§ 1036.235 and 1036.241 to determine which engine configurations within the engine family are subject to testing. Note that engine fuel maps and powertrain test results also

serve as standards as described in §§ 1036.535, 1036.540, 1036.545, and 1036.630 ~~and 40 CFR 1037.550~~.

5. Amend § 1036.110 by revising paragraphs (b)(6), (9) introductory text, and (11)(ii) and (c)(1) to read as follows:

**§ 1036.110 Diagnostic controls.**

\* \* \* \* \*

(b) \* \* \*

(6) The provisions related to verification of in-use compliance in 13 CCR 1971.1(l)(4) do not apply. The provisions related to manufacturer self-testing in 13 CCR 1971.5(c) also do not apply.

\* \* \* \* \*

(9) Design compression-ignition engines to make the following additional data-stream signals available on demand with a generic scan tool according to 13 CCR 1971.1(h)(4.2), if the engine is so equipped with the relevant components and OBD monitoring is required for those components:

\* \* \* \* \*

(11) \* \* \*

(ii) Send us results from any testing you performed for certifying engine families (including equivalent engine families) with the California Air Resources Board, including the results of any testing performed under 13 CCR 1971.1(l) for verification of in-use compliance and 13 CCR 1971.5(c) for manufacturer self-testing within the deadlines set out in 13 CCR 1971.1 and 1971.5.

\* \* \* \* \*

(c) \* \* \*

(1) For inducements specified in § 1036.111 and any other AECD that derates engine output related to SCR or DPF systems, indicate the fault code for the detected problem, a description of the fault code, and the current speed restriction. For inducement faults under § 1036.111, identify whether the fault condition is for DEF ~~quantity~~ level, DEF quality, or tampering; for other faults, identify whether the fault condition is related to SCR or DPF systems. If there are additional derate stages, also indicate the next speed restriction and the time remaining until starting the next restriction. If the derate involves something other than restricting vehicle speed, such as a torque derate, adjust the information to correctly identify any current and pending restrictions.

\* \* \* \* \*

6. Amend § 1036.111 by revising paragraphs (a)(2), (b) introductory text, (d), and (e) to read as follows:

**§ 1036.111 Inducements related to SCR.**

\* \* \* \* \*

(a) \* \* \*

(2) The provisions of this section apply differently based on an individual vehicle's speed history. A vehicle's speed category is based on the OBD system's recorded value for average speed for the preceding 30 hours of non-idle engine operation. The vehicle speed category applies at the point that the engine first detects an inducement triggering a fault condition identified under paragraph (b) of this section and continues to apply until the ~~fault~~

inducement triggering condition is fully resolved as specified in paragraph (e) of this section. Non-idle engine operation includes all operating conditions except those that qualify as idle based on OBD system controls as specified in 13 CCR 1971.1(h)(5.4.10). Apply speed derates based on the following categories:

TABLE 1 TO PARAGRAPH (a)(2) OF § 1036.111—VEHICLE CATEGORIES

Vehicle category	Average speed (mi/hr)
Low-speed	speed < 15
Medium-speed	15 ≤ speed < 25
High-speed	speed ≥ 25

<sup>a</sup> A vehicle is presumed to be a high-speed vehicle if it has not yet logged 30 hours of non-idle operation.

\* \* \* \* \*

(b) Fault-Inducement triggering conditions. Create derate strategies that monitor for and trigger an inducement based on the following conditions:

\* \* \* \* \*

(d) *Derate schedule*. Engines must follow the derate schedule described in this paragraph (d) if the engine detects a fault-an inducement triggering condition identified in paragraph (b) of this section. The derate takes the form of a maximum drive speed for the vehicle. This maximum drive speed decreases over time based on hours of non-idle engine operation without regard to engine starting.

(1) Apply speed-limiting derates according to the following schedule:

TABLE 2 TO PARAGRAPH (d)(1) OF § 1036.111—DERATE SCHEDULE FOR DETECTED FAULTSINDUCEMENT TRIGGERING CONDITIONS<sup>a</sup>

High-speed vehicles		<del>Medium</del> Low-speed vehicles		Low-speed vehicles	
Hours of non-idle engine operation	Maximum speed (mi/hr)	Hours of non-idle engine operation	Maximum speed (mi/hr)	Hours of non-idle engine operation	Maximum speed (mi/hr)
0	65	0	55	0	45
6	60	6	50	5	40
12	55	12	45	10	35
20	50	45	40	30	25
86	45	70	35	—	—
119	40	90	25	—	—
144	35	—	—	—	—
164	25	—	—	—	—

<sup>a</sup>Hours start counting when the engine detects an inducement triggering a fault condition specified in paragraph (b) of this section. For DEF supply, you may program the engine to reset the timer to three hours when the engine detects an empty DEF tank.

(2) You may design and produce engines that will be installed in motorcoaches with an alternative derate schedule that starts with a 65 mi/hr derate when a fault-an inducement triggering condition is first detected, steps down to 50 mi/hr after 80 hours, and concludes with a final derate speed of 25 mi/hr after 180 hours of non-idle operation.

(e) *Deactivating derates*. Program the engine to deactivate derates as follows:

- (1) Evaluate whether the detected ~~fault~~inducement triggering condition continues to apply. Deactivate derates if the engine confirms that the detected ~~fault~~inducement triggering condition is resolved.
- (2) Allow a generic scan tool to deactivate inducement ~~triggering related fault~~ codes while the vehicle is not in motion.
- (3) Treat any detected ~~fault~~inducement triggering condition that recurs within 40 hours of engine operation as the same detected ~~fault~~inducement triggering condition, which would restart the derate at the same point in the derate schedule that the system last deactivated the derate.

7. Amend § 1036.120 by revising paragraph (c) to read as follows:

**§ 1036.120 Emission-related warranty requirements.**

\* \* \* \* \*

(c) *Components covered.* The emission-related warranty covers all components listed in 40 CFR part 1068, appendix A, and components from any other system you develop to control emissions. Note that this includes hybrid system components when a manufacturer’s certified configuration includes hybrid system components. The emission-related warranty covers any components, regardless of the company that produced them, that are the original components or the same design as components from the certified configuration.

\* \* \* \* \*

8. Amend § 1036.125 by revising paragraph (h)(8)(iii) to read as follows:

**§ 1036.125 Maintenance instructions and allowable maintenance.**

\* \* \* \* \*

(h) \* \* \*

(8) \* \* \*

(iii) A description of the three types of SCR-related derates (DEF ~~quality level~~, DEF quality and tampering) and that further information on the inducement cause (e.g., trouble codes) is available using the OBD system.

\* \* \* \* \*

9. Amend § 1036.150 by revising paragraphs (d), (f), (j), and (k) introductory text and adding paragraph (aa) to read as follows:

**§ 1036.150 Interim provisions.**

\* \* \* \* \*

(d) *Small manufacturers.* The greenhouse gas standards of this part apply on a delayed schedule for manufacturers meeting the small business criteria specified in 13 CFR 121.201. Apply the small business criteria for NAICS code 336310 for engine manufacturers with respect to gasoline-fueled engines and 333618 for engine manufacturers with respect to other engines; the employee limits apply to the total number employees together for affiliated companies. Qualifying small manufacturers are not subject to the greenhouse gas emission standards in § 1036.108 for engines with a date of manufacture on or after November 14, 2011 but before January 1, 2022. In addition, qualifying small manufacturers producing engines that run on any fuel other than gasoline, E85, or diesel fuel may delay complying with every later greenhouse gas standard under this part by one model year; however, small manufacturers may generate emission credits only by certifying all their engine families within a given averaging set to

~~standards that apply for the current model year. Small manufacturers may certify their engines and generate emission credits under this part before standards start to apply, but only if they certify their entire U.S. directed production volume within that averaging set for that model year.~~

Note that engines not yet subject to standards must nevertheless supply fuel maps to vehicle manufacturers as described in paragraph (n) of this section. Note also that engines produced by small manufacturers are subject to criteria pollutant standards.

\* \* \* \* \*

(f) Testing exemption for qualifying engines. Tailpipe CO<sub>2</sub>, CH<sub>4</sub>, HC, and CO emissions from engines fueled with neat hydrogen are deemed to be zero. No fuel mapping, and no testing for CO<sub>2</sub>, CH<sub>4</sub>, HC, or CO is required under this part for these engines.~~[Reserved]~~

\* \* \* \* \*

(j) *Alternate standards under 40 CFR part 86.* This paragraph (j) describes alternate emission standards that apply for model year 2023 and earlier ~~for~~ loose engines certified under 40 CFR 86.1819-14(k)(8). The standards of § 1036.108 do not apply for these engines. The standards in this paragraph (j) apply for emissions measured with the engine installed in a complete vehicle consistent with the provisions of 40 CFR 86.1819-14(k)(8)(vi). The only requirements of this part that apply to these engines are those in this paragraph (j), §§ 1036.115 through 1036.135, 1036.535, and 1036.540.

(k) *Limited production volume allowance under ABT.* You may produce a limited number of Heavy HDE that continue to meet the standards that applied under 40 CFR 86.007-11 in model years 2027 through 2029. The maximum number of engines you may produce under this limited production allowance is 5 percent of the annual average of your actual ~~U.S. directed~~ production volume of Heavy HDE in model years 2023-2025 for calculating emission credits under § 1036.705. Engine certification under this paragraph (k) is subject to the following conditions and requirements:

\* \* \* \* \*

(aa) Correcting credit calculations. If you notify us by October 1, 2024 that errors mistakenly decreased your balance of emission credits for 2020 or any earlier model years, you may correct the errors and recalculate the balance of emission credits after applying a 10 percent discount to the credit correction.

### Subpart C—Certifying Engine Families

10. Amend § 1036.205 by revising paragraph (v) to read as follows:

#### **§ 1036.205 Requirements for an application for certification.**

\* \* \* \* \*

(v) Include good-faith estimates of ~~nationwide-U.S.-directed~~ production volumes. Include a justification for the estimated production volumes if they are substantially different than actual production volumes in earlier years for similar models.

\* \* \* \* \*

11. Amend § 1036.240 by revising paragraph (c)(3) to read as follows:

#### **§ 1036.240 Demonstrating compliance with criteria pollutant emission standards.**

\* \* \* \* \*

(c) \* \* \*

(3) *Sawtooth and other nonlinear deterioration patterns.* The deterioration factors described in paragraphs (c)(1) and (2) of this section assume that the highest useful life emissions occur either at the end of useful life or at the low-hour test point. The provisions of this paragraph (c)(3) apply where good engineering judgment indicates that the highest useful life emissions will occur between these two points. For example, emissions may increase with service accumulation until a certain maintenance step is performed, then return to the low-hour emission levels and begin increasing again. Such a pattern may occur with battery-based ~~electric~~ hybrid engines or hybrid powertrains. Base deterioration factors for engines with such emission patterns on the difference between (or ratio of) the point at which the highest emissions occur and the low-hour test point. Note that this applies for maintenance-related deterioration only where we allow such critical emission-related maintenance.

\* \* \* \* \*

12. Amend § 1036.241 by revising paragraph (c)(3) to read as follows:

**§ 1036.241 Demonstrating compliance with greenhouse gas emission standards.**

\* \* \* \* \*

(c) \* \* \*

(3) *Sawtooth and other nonlinear deterioration patterns.* The deterioration factors described in paragraphs (c)(1) and (2) of this section assume that the highest useful life emissions occur either at the end of useful life or at the low-hour test point. The provisions of this paragraph (c)(3) apply where good engineering judgment indicates that the highest useful life emissions will occur between these two points. For example, emissions may increase with service accumulation until a certain maintenance step is performed, then return to the low-hour emission levels and begin increasing again. Such a pattern may occur with battery-based ~~electric~~ hybrid engines or hybrid powertrains. Base deterioration factors for engines with such emission patterns on the difference between (or ratio of) the point at which the highest emissions occur and the low-hour test point. Note that this applies for maintenance-related deterioration only where we allow such critical emission-related maintenance.

\* \* \* \* \*

13. Amend § 1036.245 by revising paragraphs (c)(3) introductory text and (c)(3)(ii) introductory text to read as follows:

**§ 1036.245 Deterioration factors for exhaust emission standards.**

\* \* \* \* \*

(c) \* \* \*

(3) Perform service accumulation in the laboratory by operating the engine or hybrid powertrain repeatedly over one of the following test sequences, or a different test sequence that we approve in advance:

\* \* \* \* \*

(ii) Duty-cycle sequence 2 is based on operating over the LLC and the vehicle-based duty cycles from 40 CFR part 1037. Select the vehicle subcategory and vehicle configuration from § 1036.540 or § 1036.545 with the highest reference cycle work for each vehicle-based duty cycle. Operate the engine as follows for duty-cycle sequence 2:

\* \* \* \* \*

14. Amend § 1036.250 by revising paragraph (a) to read as follows:

**§ 1036.250 Reporting and recordkeeping for certification.**

(a) By September 30 following the end of the model year, send the Designated Compliance Officer a report including the total ~~nationwide-U.S.-directed~~ production volume of engines you produced in each engine family during the model year (based on information available at the time of the report). Report the production by serial number and engine configuration. You may combine this report with reports required under subpart H of this part. We may waive the reporting requirements of this paragraph (a) for small manufacturers.

\* \* \* \* \*

**Subpart D— Testing Production Engines and Hybrid Powertrains**

15. Amend § 1036.301 by revising paragraph (c) to read as follows:

**§ 1036.301 Measurements related to GEM inputs in a selective enforcement audit.**

\* \* \* \* \*

(c) If your certification includes powertrain testing as specified in 40 CFR 1036.630, these selective enforcement audit provisions apply with respect to powertrain test results as specified in 40 CFR part 1037, subpart D, and ~~§40-CFR 1037.1036.5450~~. We may allow manufacturers to instead perform the engine-based testing to simulate the powertrain test as specified in 40 CFR 1037.551.

\* \* \* \* \*

**Subpart E—In-use Testing**

16. Amend § 1036.405 by revising paragraphs (a)(1) and (3) and (d) to read as follows:

**§ 1036.405 Overview of the manufacturer-run field-testing program.**

(a) \* \* \*

(1) We may select up to 25 percent of your engine families in any calendar year, calculated by dividing the number of engine families you certified in the model year corresponding to the calendar year by four and rounding to the nearest whole number. We will consider only engine families with annual ~~U.S.-directed nationwide~~ production volumes above 1,500 units in calculating the number of engine families subject to testing each calendar year under the annual 25 percent engine family limit. If you have only three or fewer families that each exceed an annual ~~U.S.-directed nationwide~~ production volume of 1,500 units, we may select one engine family per calendar year for testing.

\* \* \* \* \*

(3) We will not select engine families for testing under this subpart from a given model year if your total ~~U.S.-directed nationwide~~ production volume was less than 100 engines.

\* \* \* \* \*

(d) You must complete all the required testing and reporting under this subpart (for all ten test engines, if applicable), within 18 months after we ~~direct you to test a particular engine family receive your proposed plan for recruiting, screening, and selecting vehicles~~. We will typically select engine families for testing and notify you in writing by June 30 of the applicable calendar year. If you request it, we may allow additional time to send us this information.

\* \* \* \* \*



17. Amend § 1036.420 by revising paragraph (a) to read as follows:

**§ 1036.420 Pass criteria for individual engines.**

\* \* \* \* \*

(a) Determine the emission standard for each regulated pollutant for each bin by adding the following accuracy margins for PEMS to the off-cycle standards in § 1036.104(a)(3):

TABLE 1 TO PARAGRAPH (a) OF § 1036.420—ACCURACY MARGINS FOR IN-USE TESTING

	NO <sub>x</sub>	HC	PM	CO
Bin 1	0.4 g/hr	-	-	-
Bin 2	5 mg/hp·hr	10 mg/hp·hr	6 mg/hp·hr	0.025 g/hp·hr

\* \* \* \* \*

**Subpart F—Test Procedures**

18. Amend § 1036.501 by adding paragraph (g) to read as follows:

**§ 1036.501 General testing provisions.**

\* \* \* \* \*

(g) For testing engines that use regenerative braking through the crankshaft to only power an electric heater for aftertreatment devices, you may use the fuel mapping procedure in § 1036.505(b)(1) or (2) and the nonhybrid engine testing procedures in §§ 1036.510, 1036.512, and 1036.514, as long as the recovered energy is less than 10 percent of the total positive work for each applicable transient duty cycle. Otherwise, use powertrain testing procedures specified for hybrid engines or hybrid powertrains to create fuel maps and measure emissions. For engines that power an electric heater with a battery, you must meet the requirements related to charge-sustaining operation as described in 40 CFR 1066.501.

19. Amend § 1036.505 by revising paragraphs (a), (b) introductory text, and (b)(3) and (4) to read as follows:

**§ 1036.505 Engine data and information to support vehicle certification.**

\* \* \* \* \*

(a) Identify engine make, model, fuel type, combustion type, engine family name, calibration identification, and engine displacement. Also identify whether the engines meet CO<sub>2</sub> standards for tractors, vocational vehicles, or both. When certifying vehicles with GEM, for any fuel type not identified in Table 1 of § 1036.550, select fuel type as diesel fuel for engines subject to compression-ignition standards, and select fuel type as gasoline for engines subject to spark-ignition standards.

(b) This paragraph (b) describes four different methods to generate engine fuel maps. For engines without hybrid components and for mild hybrid engines where you do not include hybrid components in the test, generate fuel maps using either paragraph (b)(1) or (2) of this section. For other hybrid engines, generate fuel maps using paragraph (b)(3) of this section. For hybrid powertrains and nonhybrid powertrains and for vehicles where the transmission is not automatic, automated manual, manual, or dual-clutch, generate fuel maps using paragraph (b)(4) of this section.

\* \* \* \* \*

(3) Determine fuel consumption at idle as described in § 1036.535(c) and (d) and determine cycle-average engine fuel maps as described in ~~§40-CFR 10367.5450~~, including cycle-average engine fuel maps for highway cruise cycles. Set up the test to apply accessory load for all operation by primary intended service class as described in the following table:

TABLE 1 TO PARAGRAPH (b)(3) OF § 1036.505—ACCESSORY LOAD

Primary Intended Service Class	Power Representing Accessory Load (kW)
Light HDV	1.5
Medium HDV	2.5
Heavy HDV	3.5

(4) Generate powertrain fuel maps as described in ~~§40-CFR 10367.5450~~ instead of fuel mapping under § 1036.535 or § 1036.540. Note that the option in ~~§40-CFR 10367.5450(b)(2)~~ is allowed only for hybrid engine testing. Disable stop-start systems and automatic engine shutdown systems when conducting powertrain fuel map testing using ~~§40-CFR 10367.5450~~.

\* \* \* \* \*

20. Amend § 1036.510 by:

- a. Revising paragraphs (b)(2) introductory text, (b)(2)(vii), and (b)(2)(viii).
- b. Removing paragraph (b)(2)(ix).
- c. Revising paragraphs (c)(2)(i) introductory text, (d) introductory text, and (d)(1) and (2)(ii).
- d. Revising the heading in Figure 1 to paragraph (d)(4) by removing the period.
- e. Revising paragraphs (e), (f), and (g).

The revisions read as follows:

**§ 1036.510 Supplemental Emission Test.**

\* \* \* \* \*

(b) \* \* \*

(2) Test hybrid engines and hybrid powertrains as described in ~~§40-CFR 10367.5450~~, except as specified in this paragraph (b)(2). Do not compensate the duty cycle for the distance driven as described in ~~§40-CFR 10367.5450(g)(4)~~. For hybrid engines, select the transmission from Table 1 of § 1036.540, substituting “engine” for “vehicle” and “highway cruise cycle” for “SET”. Disregard duty cycles in ~~§40-CFR 10367.5450(j)~~. For cycles that begin with idle, leave the transmission in neutral or park for the full initial idle segment. Place the transmission into drive no earlier than 5 seconds before the first nonzero vehicle speed setpoint. For SET testing only, place the transmission into park or neutral when the cycle reaches the final idle segment. Use the following vehicle parameters instead of those in ~~§40-CFR 10367.5450~~ to define the vehicle model in ~~§40-CFR 10367.5450(a)(3)~~:

\* \* \* \* \*

(vii) Select a combination of drive axle ratio,  $k_a$ , and a tire radius,  $r$ , that represents the worst-case combination of final gear ratio, drive axle ratio, and tire size for CO<sub>2</sub> expected for vehicles in which the hybrid powertrain-engine or hybrid engine-powertrain will be installed. This is typically the highest axle ratio and smallest tire radius. In selecting a drive axle ratio and tire radius, if representative, ensure that the maximum vehicle speed is no less than 60 mi/hr. Manufacturers may request preliminary approval for selected drive axle ratio and tire radius consistent with the provisions of § 1036.210. If the hybrid

engine or hybrid powertrain is used exclusively in vehicles which are not capable of reaching 60 mi/hr, follow the provisions of 40 CFR 1066.425(b)(5). Note for hybrid engines the final gear ratio can change depending on the duty-cycle, which will change the selection of the drive axle ratio and tire size. For example, § 1036.520 prescribes a different top gear ratio than paragraph (b)(2) of this section.

~~(viii) Select a tire radius,  $r$ , that represents the worst case pair of tire size and drive axle ratio for CO<sub>2</sub> expected for vehicles in which the hybrid powertrain or hybrid engine will be installed. This is typically the smallest tire radius.~~

~~(ix)~~ If you are certifying a hybrid engine, use a default transmission efficiency of 0.95 and create the vehicle model along with its default transmission shift strategy as described in ~~§40-CFR 10367.5450~~ § 1036.540(a)(3)(ii). Use the transmission parameters defined in Table 1 of § 1036.540 to determine transmission type and gear ratio. For Light HDV and Medium HDV, use the Light HDV and Medium HDV parameters for FTP, LLC, and SET duty cycles. For Tractors and Heavy HDVs, use the Tractor and Heavy HDV transient cycle parameters for the FTP and LLC duty cycles and the Tractor and Heavy HDV highway cruise cycle parameters for the SET duty cycle.

(c) \* \* \*

(2) \* \* \*

(i) Determine road grade at each point based on the continuous rated power of the hybrid powertrain-system,  $P_{\text{contrated}}$ , in kW determined in § 1036.520, the vehicle speed (A, B, or C) in mi/hr for a given SET mode,  $v_{\text{ref[speed]}}$ , and the specified road-grade coefficients using the following equation:

\* \* \* \* \*

(d) Determine criteria pollutant emissions for plug-in hybrid engines and plug-in hybrid powertrains as follows:

(1) Precondition the engine or powertrain in charge-sustaining mode. Perform testing as described in this section for hybrid engines ~~and-or~~ hybrid powertrains in charge-sustaining mode.

(2) \* \* \*

(ii) Operate the ~~hybrid~~ engine or powertrain continuously over repeated SET duty cycles until you reach the end-of-test criterion defined in 40 CFR 1066.501(a)(3).

\* \* \* \* \*

(e) Determine greenhouse gas pollutant emissions for plug-in hybrid engines and plug-in hybrid powertrains using the emissions results for all the SET test intervals for both charge-depleting and charge-sustaining operation from paragraph (d)(2) of this section. Calculate the utility factor-weighted composite mass of emissions from the charge-depleting and charge-sustaining test results,  $e_{\text{UF[emission]comp}}$ , using the following equation:

$$e_{\text{UF[emission]comp}} = \frac{\sum_{i=1}^N [e_{\text{[emission][int]CDi}} \cdot (UF_{\text{DCDi}} - UF_{\text{DCDi-1}})] + \sum_{j=1}^M [e_{\text{[emission][int]CSj}}]}{(1 - UF_{\text{RCD}})} \cdot M$$

Eq. 1036.510-10

Where:

$i$  = an indexing variable that represents one test interval.

$N$  = total number of charge-depleting test intervals.

$e_{\text{[emission][int]CD}i}$  = total mass of emissions in the charge-depleting portion of the test for each test interval,  $i$ , starting from  $i = 1$ , including the test interval(s) from the transition phase.

$UF_{\text{DCD}i}$  = utility factor fraction at distance  $D_{\text{CD}i}$  from Eq. 1036.510-11, as determined by interpolating the approved utility factor curve for each test interval,  $i$ , starting from  $i = 1$ . Let  $UF_{\text{DCD}0} = 0$ .

$j$  = an indexing variable that represents one test interval.

$M$  = total number of charge-sustaining test intervals.

$e_{\text{[emission][int]CS}j}$  = total mass of emissions in the charge-sustaining portion of the test for each test interval,  $j$ , starting from  $j = 1$ .

$UF_{\text{RCD}}$  = utility factor fraction at the full charge-depleting distance,  $R_{\text{CD}}$ , as determined by interpolating the approved utility factor curve.  $R_{\text{CD}}$  is the cumulative distance driven over  $N$  charge-depleting test intervals.

$$D_{\text{CD}i} = \sum_{k=1}^Q (v_k \cdot \Delta t)$$

Eq. 1036.510-11

Where:

$k$  = an indexing variable that represents one recorded velocity value.

$Q$  = total number of measurements over the test interval.

$v$  = vehicle velocity at each time step,  $k$ , starting from  $k = 1$ . For tests completed under this section,  $v$  is the vehicle velocity from the vehicle model in ~~§40-CFR 10367.5450~~. Note that this should include charge-depleting test intervals that start when the engine is not yet operating.

$\Delta t = 1/f_{\text{record}}$

$f_{\text{record}}$  = the record rate.

*Example using the charge-depletion test in Figure 1 of § 1036.510 for the SET for CO<sub>2</sub> emission determination:*

$Q = 24000$

$v_1 = 0$  mi/hr

$v_2 = 0.8$  mi/hr

$v_3 = 1.1$  mi/hr

$f_{\text{record}} = 10$  Hz

$\Delta t = 1/10$  Hz = 0.1 s

$$D_{\text{CD}1} = \sum_{k=1}^{24000} (0 \cdot 0.1 + 0.8 \cdot 0.1 + 1.1 \cdot 0.1 + v_{24000} \cdot \Delta t)$$

$D_{\text{CD}1} = 30.1$  mi

$D_{\text{CD}2} = 30.0$  mi

$D_{\text{CD}3} = 30.1$  mi

$D_{\text{CD}4} = 30.2$  mi

$D_{\text{CD}5} = 30.1$  mi

$N = 5$

$UF_{\text{DCD}1} = 0.11$

$UF_{\text{DCD}2} = 0.23$

$UF_{\text{DCD}3} = 0.34$

$UF_{\text{DCD}4} = 0.45$

$$UF_{DCD5} = 0.53$$

$$e_{CO2SETCD1} = 0 \text{ g/hp}\cdot\text{hr}$$

$$e_{CO2SETCD2} = 0 \text{ g/hp}\cdot\text{hr}$$

$$e_{CO2SETCD3} = 0 \text{ g/hp}\cdot\text{hr}$$

$$e_{CO2SETCD4} = 0 \text{ g/hp}\cdot\text{hr}$$

$$e_{CO2SETCD5} = 174.4 \text{ g/hp}\cdot\text{hr}$$

$$M = 1$$

$$e_{CO2SETCS} = 428.1 \text{ g/hp}\cdot\text{hr}$$

$$UF_{RCD} = 0.53$$

$$e_{UFCO2comp} = [0 \cdot (0.11 - 0) + 0 \cdot (0.23 - 0.11) + 0 \cdot (0.34 - 0.23) + 0 \cdot (0.45 - 0.34) + 174.4 \cdot (0.53 - 0.45)] + 428.1 \cdot \frac{(1 - 0.53)}{1}$$

$$e_{UFCO2comp} = 215.2 \text{ g/hp}\cdot\text{hr}$$

(f) Calculate and evaluate cycle statistics as specified in 40 CFR 1065.514 for nonhybrid engines and ~~§40-CFR 10367.5450~~ for hybrid engines and hybrid powertrains.

(g) Calculate the total emission mass of each constituent,  $m$ , over the test interval as described in 40 CFR 1065.650. For nonhybrid engines, calculate the total work,  $W$ , over the test interval as described in 40 CFR 1065.650(d). For hybrid engines and hybrid powertrains, c~~Calculate total positive cycle-work over the test interval for powertrain testing~~ using system power,  $P_{sys}$ .

Determine  $P_{sys}$ , using § 1036.520(f).

21. Amend § 1036.512 by:

- a. Revising paragraphs (b)(2)(v), (c), (d) introductory text, (d)(1) and (2)(ii).
- b. Revising the heading in Figure 1 to paragraph (d)(4) by removing the period.
- c. Revising paragraph (f).

The revisions read as follows:

**§ 1036.512 Federal Test Procedure.**

\* \* \* \* \*

(b) \* \* \*

(2) \* \* \*

(v) For plug-in hybrid engines and plug-in hybrid powertrains, test over the FTP in both charge-sustaining and charge-depleting operation for both criteria and greenhouse gas pollutant determination.

(c) The FTP duty cycle consists of an initial run through the test interval from a cold start as described in 40 CFR part 1065, subpart F, followed by a  $(20 \pm 1)$  minute hot soak with no engine operation, and then a final hot start run through the same transient test interval. Engine starting is part of both the cold-start and hot-start test intervals. Calculate the total emission mass of each constituent,  $m$ , ~~and the total work,  $W$ ,~~ over each test interval as described in 40 CFR 1065.650. For nonhybrid engines, calculate the total work,  $W$ , over the test interval as described in 40 CFR 1065.650(d). For hybrid engines and hybrid powertrains, cCalculate total positive work over each test interval ~~for powertrain testing~~ using system power,  $P_{sys}$ . Determine  $P_{sys}$  using § 1036.520(f). For powertrains with automatic transmissions, account for and include the work produced by the engine from the CITT load. Calculate the official transient emission result from the cold-start and hot-start test intervals using the following equation:

$$\text{Official transient emission result} = \frac{\text{cold start emissions (g)} + 6 \cdot \text{hot start emissions (g)}}{\text{cold start work (hp}\cdot\text{hr)} + 6 \cdot \text{hot start work (hp}\cdot\text{hr)}}$$

Eq. 1036.512-1

(d) Determine criteria pollutant emissions for plug-in hybrid engines and plug-in hybrid powertrains as follows:

(1) Precondition the engine or powertrain in charge-sustaining mode. Perform testing as described in this section for hybrid engines ~~and-or~~ hybrid powertrains in charge-sustaining mode.

(2) \* \* \*

(ii) Operate the ~~hybrid~~ engine or powertrain over one FTP duty cycle followed by alternating repeats of a 20-minute soak and a hot start test interval until you reach the end-of-test criteria defined in 40 CFR 1066.501.

\* \* \* \* \*

(f) Calculate and evaluate cycle statistics as specified in 40 CFR 1065.514 for nonhybrid engines and ~~§40-CFR 10367.5450~~ for hybrid engines and hybrid powertrains.

22. Amend § 1036.514 to read as follows:

### § 1036.514 Low Load Cycle.

(a) Measure emissions using the transient Low Load Cycle (LLC) as described in this section to determine whether engines meet the LLC emission standards in § 1036.104.

(b) The LLC duty cycle is described in paragraph (d) of appendix B of this part. The following procedures apply differently for testing nonhybrid engines, hybrid engines, and hybrid powertrains:

(1) For nonhybrid engine testing, use the following procedures:

(i) Use the ~~duty cycle is based on~~ normalized speed and torque values for engine testing in the LLC duty cycle described in paragraph (d) of appendix B of this part.

(ii) Denormalize speed and torque values as described in 40 CFR 1065.512. ~~Denormalize torque as described in 40 CFR and~~ 1065.610 with the following additional requirements~~(d)~~:

(A) The accessory load at idle described in paragraph (c) of this section must be applied using the optional declared idle power in 40 CFR 1065.510(f)(6). Use of the optional declared idle torque in 40 CFR 1065.510(f)(5)(iii) is not allowed and must be zero.

(B) Replace paragraph 40 CFR 1065.610(d)(3)(vi) with the following:

(1) For all other idle segments less than or equal to 200 s in length, set the reference speed and torque values to the warm-idle-in-drive values. This is to represent the transmission operating in drive.

(2) For idle segments more than 200 s in length, set the reference speed and torque values to the warm-idle-in-drive values for the first three seconds and the last three seconds of the idle segment. For all other points in the idle segment set the reference speed and torque values to the warm-idle-in-neutral values. This is to represent the transmission being manually shifted from drive to neutral near the beginning of the idle segment and back to drive near the end of the idle segment.

(iii) Calculate and evaluate cycle statistics as described in 40 CFR 1065.514. For testing spark-ignition gaseous-fueled engines with fuel delivery at a single-point in the intake manifold, you may apply the statistical criteria in Table 1 in this section to validate the LLC.

TABLE 1 TO PARAGRAPH (b)(1)(iii) OF § 1036.514—STATISTICAL CRITERIA FOR VALIDATING DUTY CYCLES FOR GASEOUS-FUELED SPARK-IGNITION ENGINES<sup>a</sup>

<u>Parameter</u>	<u>Speed</u>	<u>Torque</u>	<u>Power</u>
<u>Slope, <math>a_1</math></u>	<u>—</u>	<u><math>0.800 \leq a_1 \leq 1.030</math></u>	<u><math>0.800 \leq a_1 \leq 1.030</math></u>
<u>Absolute value of intercept, <math> a_0 </math></u>	<u>—</u>	<u>—</u>	<u>—</u>
<u>Standard error of the estimate, <math>SEE</math></u>	<u>—</u>	<u>—</u>	<u><math>\leq 15\%</math> of maximum mapped power</u>
<u>Coefficient of determination, <math>r^2</math></u>	<u>—</u>	<u><math>\geq 0.650</math></u>	<u><math>\geq 0.650</math></u>

<sup>a</sup>Statistical criteria apply as specified in 40 CFR 1065.514 unless otherwise specified.

~~(ii) For idle segments more than 200 seconds, set reference torques to the torque needed to meet the accessory loads in Table 1 of this section instead of CITT. This is to represent shifting the transmission to park or neutral at the start of the idle segment. Change the reference torque to CITT no earlier than 5 seconds before the end of the idle segment. This is to represent shifting the transmission to drive.~~

(2) Test hybrid engines and hybrid powertrains as described in § 1036.510(b)(2), with the following exceptions:

(i) Replace  $P_{\text{contrated}}$  with  $P_{\text{rated}}$ , which is the peak rated power determined in § 1036.520.

(ii) Keep the transmission in drive for all idle segments 200 seconds or less. For idle segments more than 200 seconds, ~~leave the transmission in drive for the first 3 seconds of the idle segment, place place~~ the transmission in park or neutral ~~immediately after the 3rd second in at the start of~~ the idle segment, and ~~place-shift~~ the transmission into drive again ~~no earlier than 53~~ seconds before the ~~end of the idle segment which is defined by the~~ first nonzero vehicle speed setpoint.

(iii) For hybrid engines, select the transmission from Table 1 of § 1036.540, substituting “engine” for “vehicle”.

(iv) For hybrid engines, you may request to change the ~~GEM-generated engine - commanded-reference~~ torque at idle to better represent curb idle transmission torque (CITT).

(v) For plug-in hybrid engines and ~~plug-in hybrid~~ powertrains, determine criteria pollutant and greenhouse gas emissions as described in § 1036.510(d) and (e), replacing “SET” with “LLC”.

~~(vi) Calculate and evaluate cycle statistics as specified in § 1036.545.~~

(c) ~~Set dynamometer torque demand such that~~ Apply a vehicle power represents an accessory load for ~~all each~~ idle operation point in the cycle based on a constant power. Use the power values as described in Table 1-2 of to paragraph (c)(43) of this section for each based on primary intended service class. ~~For nonhybrid engine testing, this is in addition to any applicable CITT.~~ Additional provisions related to vehicle accessory load apply for the following special cases:

(1) For engines with stop-start technology, account for ~~the loss of mechanical work due to the lack of any idle~~ accessory load during engine-off conditions by determining the total ~~loss of mechanical work from idle accessory load during all~~ engine-off ~~power demand~~ intervals over the ~~entire~~ test interval and distributing that ~~load-work~~ over the engine-on ~~portions-intervals~~ of the ~~entire~~ test interval based on a calculated average power. You may determine the engine-off time by running practice cycles or through engineering analysis.

(2) Apply vehicle accessory power loads on idle points for hybrid powertrain testing where torque is measured at the axle input shaft or wheel hubsthat includes the transmission either as a mechanical or electrical load.

(3) ~~You may apply the following deviations from specified torque settings for smoother idle (other than idle that includes motoring), or you may develop different procedures for adjusting accessory load at idle consistent with good engineering judgment:~~

~~(i) Set the reference torque to correspond to the applicable accessory load for all points with normalized speed at or below zero percent and reference torque from zero up to the torque corresponding to the accessory load.~~

~~(ii) Change the reference torques to correspond to the applicable accessory load for consecutive points with reference torques from zero up to the torque corresponding to the accessory load that immediately precedes or follows idle points.~~

~~(4) Table 1-2 follows:~~

TABLE 1-2 TO PARAGRAPH (C)(43) OF § 1036.514—ACCESSORY LOAD AT IDLE

Primary intended service class	Power representing accessory load (kW)
Light HDE	1.5
Medium HDE	2.5
Heavy HDE	3.5

(d) The test sequence consists of preconditioning the engine by running one or two FTPs with each FTP followed by (20 ±1) minutes with no engine operation and a hot start run through the LLC. You may start any preconditioning FTP with a hot engine. Perform testing as described in 40 CFR 1065.530 for a test interval that includes engine starting. Calculate the total emission mass of each constituent, *m*, over the test interval and the total work, *W*, as described in 40 CFR 1065.650. For nonhybrid engines, calculate the total work, *W*, over the test interval as described in 40 CFR 1065.650(d). For hybrid engines and hybrid powertrains, cCalculate total positive work over the test interval for powertrain testing using system power,  $P_{sys}$ . Determine  $P_{sys}$  using § 1036.520(f). For powertrains with automatic transmissions, account for and include the work produced by the engine from the CITT load. ~~For batch sampling, you may sample background periodically into the bag over the course of multiple test intervals.~~

~~(e) Calculate and evaluate cycle statistics as specified in 40 CFR 1065.514 for nonhybrid engines and 40 CFR 1037.550 for hybrid engines and hybrid powertrains. For gaseous-fueled engine testing with a single point fuel injection system, you may apply all the statistical criteria in § 1036.540(d)(3) to validate the LLC.~~

23. Amend § 1036.520 by revising the introductory text, paragraphs (b) introductory text, (d)(2) and (3), (h), and (i)(2) to read as follows:

**§ 1036.520 Determining power and vehicle speed values for powertrain testing.**

This section describes how to determine the system peak power and continuous rated power of hybrid and nonhybrid powertrain systems and the vehicle speed for carrying out duty-cycle testing under this part and ~~§40-CFR 10367.5450~~.

\* \* \* \* \*

(b) Set up the powertrain test according to ~~§40-CFR 10367.5450~~, with the following exceptions:

\* \* \* \* \*

(d) \* \* \*



(2) Set maximum driver demand for a full load acceleration at 6.0 % road grade with an initial vehicle speed of 0 mi/hr, continuing for 268 seconds. You may decrease the road grade in the first 30 seconds or increase initial vehicle speed up to 5 mi/hr as needed to mitigate clutch slip.

(3) Linearly ramp the grade from 6.0 % down to 0.0 % over 300 seconds. Stop the test after the acceleration is less than 0.02 m/s<sup>2</sup> 30 seconds after the grade setpoint has reached 0.0 %.

\* \* \* \* \*

(h) Determine rated power,  $P_{\text{rated}}$ , as the maximum measured power from the data collected in paragraph (d)(2) of this section where the COV determined that meets the specifications in paragraph (g) of this section is less than 2 %.

(i) \* \* \*

(2) For hybrid powertrains,  $P_{\text{contrated}}$  is the maximum measured power from the data collected in paragraph (d)(3) of this section where the COV determined that meets the specifications in paragraph (g) of this section is less than 2 %.

\* \* \* \* \*

24. Amend § 1036.525 by revising the introductory text to read as follows:

**§ 1036.525 Clean Idle test.**

Measure emissions using the procedures described in this section to determine whether engines and hybrid powertrains meet the clean idle emission standards in § 1036.104(b). For plug-in hybrid engines and plug-in hybrid powertrains, perform the test with the hybrid function disabled.

\* \* \* \* \*

25. Amend § 1036.530 by adding paragraph (j) to read as follows:

**§ 1036.530 Test procedures for off-cycle testing.**

\* \* \* \* \*

(j) Fuel other than carbon-containing. The following procedures apply for testing engines using at least one fuel that is not a carbon-containing fuel:

(1) Use the following equation to determine  $m_{\text{CO}_2, \text{norm}, \text{testinterval}}$  instead of Eq. 1036.530-2:

$$m_{\text{CO}_2, \text{norm}, \text{testinterval}} = \frac{W_{\text{testinterval}}}{P_{\text{max}} \cdot t_{\text{testinterval}}}$$

Eq. 1036.530-6

Where:

$W_{\text{testinterval}}$  = total positive work over the test interval as determined in 40 CFR 1065.650.

$P_{\text{max}}$  = the highest value of rated power for all the configurations included in the engine family.

$t_{\text{testinterval}}$  = duration of the test interval. Note that the nominal value is 300 seconds.

Example:

$W_{\text{testinterval}} = 8.95 \text{ hp}\cdot\text{hr}$

$P_{\text{max}} = 406.5 \text{ hp}$

$t_{\text{testinterval}} = 300.01 \text{ s} = 0.08 \text{ hr}$

$$m_{\text{CO}_2, \text{norm}, \text{testinterval}} = \frac{8.95}{406.5 \cdot 0.08}$$

$$m_{\text{CO}_2, \text{norm}, \text{testinterval}} = 0.2722$$

$$m_{\text{CO}_2, \text{norm}, \text{testinterval}} = 27.22 \%$$

(2) Determine off-cycle emissions quantities as follows:

(i) For engines subject to spark-ignition standards, use the following equation instead of Eq. 1036.530-3:

$$e_{[\text{emissions}], \text{offcycle}} = \frac{m_{[\text{emission}]}}{W_{\text{testinterval}}}$$

Eq. 1036.530-7

Where:

$m_{[\text{emission}]}$  = total emission mass for a given pollutant over the test interval as determined in paragraph (d)(2) of this section.

$W_{\text{testinterval}}$  = total positive work over the test interval as determined in 40 CFR 1065.650.

Example:

$$m_{\text{NO}_x} = 1.337 \text{ g}$$

$$W_{\text{testinterval}} = 38.2 \text{ hp}\cdot\text{hr}$$

$$e_{\text{NO}_x, \text{offcycle}} = \frac{1.337}{38.2}$$

$$e_{\text{NO}_x, \text{offcycle}} = 0.035 \text{ g}/\text{hp}\cdot\text{hr}$$

(ii) For engines subject to compression-ignition standards, use Eq. 1036.530-4 to determine the off-cycle emission quantity for bin 1.

(iii) For engines subject to compression-ignition standards, use the following equation instead of Eq. 1036.530-5 to determine the off-cycle emission quantity for bin 2:

$$e_{[\text{emissions}], \text{offcycle}, \text{bin2}} = \frac{\sum_{i=1}^N m_{[\text{emission}], \text{testinterval}, i}}{\sum_{i=1}^N W_{\text{testinterval}, i}}$$

Eq. 1036.530-8

Where:

$i$  = an indexing variable that represents one 300 second test interval.

$N$  = total number of 300 second test intervals in bin 2.

$m_{[\text{emission}], \text{testinterval}, i}$  = total emission mass for a given pollutant over the test interval  $i$  in bin 2 as determined in paragraph (d)(2) of this section.

$W_{\text{testinterval}, i}$  = total positive work over the test interval  $i$  in bin 2 as determined in 40 CFR 1065.650.

Example:

$$N = 15439$$

$$m_{\text{NO}_x1} = 0.546 \text{ g}$$

$$m_{\text{NO}_x2} = 0.549 \text{ g}$$

$$m_{\text{NO}_x3} = 0.556 \text{ g}$$

$$W_{\text{testinterval1}} = 8.91 \text{ hp}\cdot\text{hr}$$

$$W_{\text{testinterval2}} = 8.94 \text{ hp}\cdot\text{hr}$$

$$W_{\text{testinterval3}} = 8.89 \text{ hp}\cdot\text{hr}$$

$$e_{\text{NOx,offcycle,bin2}} = \frac{(0.546 + 0.549 + 0.556 \dots + m_{\text{NOx,testinterval,15439}})}{(8.91 + 8.94 + 8.89 \dots + W_{\text{testinterval,15439}})}$$

$e_{\text{NOx,offcycle,bin2}} = 0.026 \text{ g/hp}\cdot\text{hr}$

26. Amend § 1036.535 by revising paragraphs (b)(1)(ii) introductory text, (b)(1)(ii)(B), (b)(1)(iii), and (b)(10) to read as follows:

**§ 1036.535 Determining steady-state engine fuel maps and fuel consumption at idle.**

\* \* \* \* \*

(b) \* \* \*

(1) \* \* \*

(ii) ~~Determine~~ Select the following ~~default~~ required torque setpoints at each of the selected speed setpoints: zero ( $T = 0$ ), maximum mapped torque,  $T_{\text{max mapped}}$ , and eight (or more) equally spaced points between  $T = 0$  and  $T_{\text{max mapped}}$ . Select the maximum torque setpoint at each speed to conform to the torque map as follows:

\* \* \* \* \*

(B) Select  $T_{\text{max}}$  at each speed setpoint as a single torque value to represent all the default torque setpoints above the value determined in paragraph (b)(1)(ii)(A) of this section. All of the other default torque setpoints less than  $T_{\text{max}}$  at a given speed setpoint are required torque setpoints.

(iii) You may select any additional speed and torque setpoints consistent with good engineering judgment. For example you may need to select additional points if the engine's fuel consumption is nonlinear across the torque map. Avoid creating a problem with interpolation between narrowly spaced speed and torque setpoints near  $T_{\text{max}}$ . For each additional speed setpoint, we recommend including a torque setpoint of  $T_{\text{max}}$ ; however, you may select torque setpoints that properly represent in-use operation. Increments for torque setpoints between these minimum and maximum values at an additional speed setpoint must be no more than one-ninth of  $T_{\text{max,mapped}}$ . Note that if the test points were added for the child rating, they should still be reported in the parent fuel map. We will test with at least as many points as you. If you add test points to meet testing requirements for child ratings, include those same test points as reported values for the parent fuel map. For our testing, we will use the same normalized speed and torque test points you use, and we may select additional test points.

\* \* \* \* \*

(10) Correct the measured or calculated mean fuel mass flow rate, at each of the ~~engine-idle~~ operating points to account for mass-specific net energy content as described in paragraph (e) of this section.

\* \* \* \* \*

27. Amend § 1036.540 by revising paragraph (b) to read as follows:

**§ 1036.540 Determining cycle-average engine fuel maps.**

\* \* \* \* \*

(b) *General test provisions.* The following provisions apply for testing under this section:

~~(1) To perform fuel mapping under this section for hybrid engines, make sure the engine and its hybrid features are appropriately configured to represent the hybrid features in your testing.~~

~~(2)~~ Measure NO<sub>x</sub> emissions for each specified sampling period in grams. You may perform these measurements using a NO<sub>x</sub> emission-measurement system that meets the requirements of 40 CFR part 1065, subpart J. Include these measured NO<sub>x</sub> values any time you report to us your fuel-consumption values from testing under this section. If a system malfunction prevents you from measuring NO<sub>x</sub> emissions during a test under this section but the test otherwise gives valid results, you may consider this a valid test and omit the NO<sub>x</sub> emission measurements; however, we may require you to repeat the test if we determine that you inappropriately voided the test with respect to NO<sub>x</sub> emission measurement.

~~(3)~~ The provisions related to carbon balance error verification in § 1036.543 apply for all testing in this section. These procedures are optional, but we will perform carbon balance error verification for all testing under this section.

~~(34)~~ Correct fuel mass to a mass-specific net energy content of a reference fuel as described in paragraph (d)(13) of this section.

~~(45)~~ This section uses engine parameters and variables that are consistent with 40 CFR part 1065.

\* \* \* \* \*

28. Revise § 1036.543 to read as follows:

**§ 1036.543 Carbon balance error verification.**

The optional carbon balance error verification in 40 CFR 1065.543 compares independent assessments of the flow of carbon through the system (engine plus aftertreatment). This procedure applies for each individual interval in §§ 1036.535(b), (c), and (d), ~~and 1036.540, and 40 CFR-10367.5450.~~

29. Add § 1036.545 to read as follows:

**§ 1036.545 Powertrain testing.**

This section describes the procedure to measure fuel consumption and create engine fuel maps by testing a powertrain that includes an engine coupled with a transmission, drive axle, and hybrid components or any assembly with one or more of those hardware elements. Engine fuel maps are part of demonstrating compliance with Phase 2 and Phase 3 vehicle standards under 40 CFR part 1037; the powertrain test procedure in this section is one option for generating this fuel-mapping information as described in § 1036.505. Additionally, this powertrain test procedure is one option for certifying hybrid engines and hybrid powertrains to the engine standards in §§ 1036.104 and 1036.108.

(a) General test provisions. The following provisions apply broadly for testing under this section:

(1) Measure NO<sub>x</sub> emissions as described in paragraph (k) of this section. Include these measured NO<sub>x</sub> values any time you report to us your greenhouse gas emissions or fuel consumption values from testing under this section.

(2) The procedures of 40 CFR part 1065 apply for testing in this section except as specified. This section uses engine parameters and variables that are consistent with 40 CFR part 1065.

(3) Powertrain testing depends on models to calculate certain parameters. You can use the detailed equations in this section to create your own models, or use the GEM HIL model contained within GEM Phase 2, Version 4.0 (incorporated by reference in 40 CFR 1037.810) to simulate vehicle hardware elements as follows:

(i) Create driveline and vehicle models that calculate the angular speed setpoint for the test cell dynamometer,  $f_{\text{ref,dyno}}$ , based on the torque measurement location. Use the detailed equations in paragraph (f) of this section, the GEM HIL model's driveline and vehicle submodels, or a combination of the equations and the submodels. You may use the GEM HIL model's transmission submodel in paragraph (f) of this section to simulate a transmission only if testing hybrid engines.

(ii) Create a driver model or use the GEM HIL model's driver submodel to simulate a human driver modulating the throttle and brake pedals to follow the test cycle as closely as possible.

(iii) Create a cycle-interpolation model or use the GEM HIL model's cycle submodel to interpolate the duty-cycles and feed the driver model the duty-cycle reference vehicle speed for each point in the duty-cycle.

(4) The powertrain test procedure in this section is designed to simulate operation of different vehicle configurations over specific duty cycles. See paragraphs (h) and (j) of this section.

(5) For each test run, record engine speed and torque as defined in 40 CFR 1065.915(d)(5) with a minimum sampling frequency of 1 Hz. These engine speed and torque values represent a duty cycle that can be used for separate testing with an engine mounted on an engine dynamometer under 40 CFR 1037.551, such as for a selective enforcement audit as described in 40 CFR 1037.301.

(6) For hybrid powertrains with no plug-in capability, correct for the net energy change of the energy storage device as described in 40 CFR 1066.501. For plug-in hybrid electric powertrains, follow 40 CFR 1066.501 to determine End-of-Test for charge-depleting operation. You must get our approval in advance for your utility factor curve; we will approve it if you can show that you created it, using good engineering judgment, from sufficient in-use data of vehicles in the same application as the vehicles in which the plug-in hybrid electric powertrain will be installed. You may use methodologies described in SAE J2841 to develop the utility factor curve.

(7) The provisions related to carbon balance error verification in § 1036.543 apply for all testing in this section. These procedures are optional if you are only performing direct or indirect fuel-flow measurement, but we will perform carbon balance error verification for all testing under this section.

(8) Do not apply accessory loads when conducting a powertrain test to generate inputs to GEM if torque is measured at the axle input shaft or wheel hubs.

(9) If you test a powertrain over the duty cycle specified in § 1036.514, control and apply the electrical accessory loads using one of the following systems:

(i) An alternator with dynamic electrical load control.

(ii) A load bank connected directly to the powertrain's electrical system.

(10) The following instruments are required with plug-in hybrid systems to determine required voltages and currents during testing and must be installed on the powertrain to measure these values during testing:

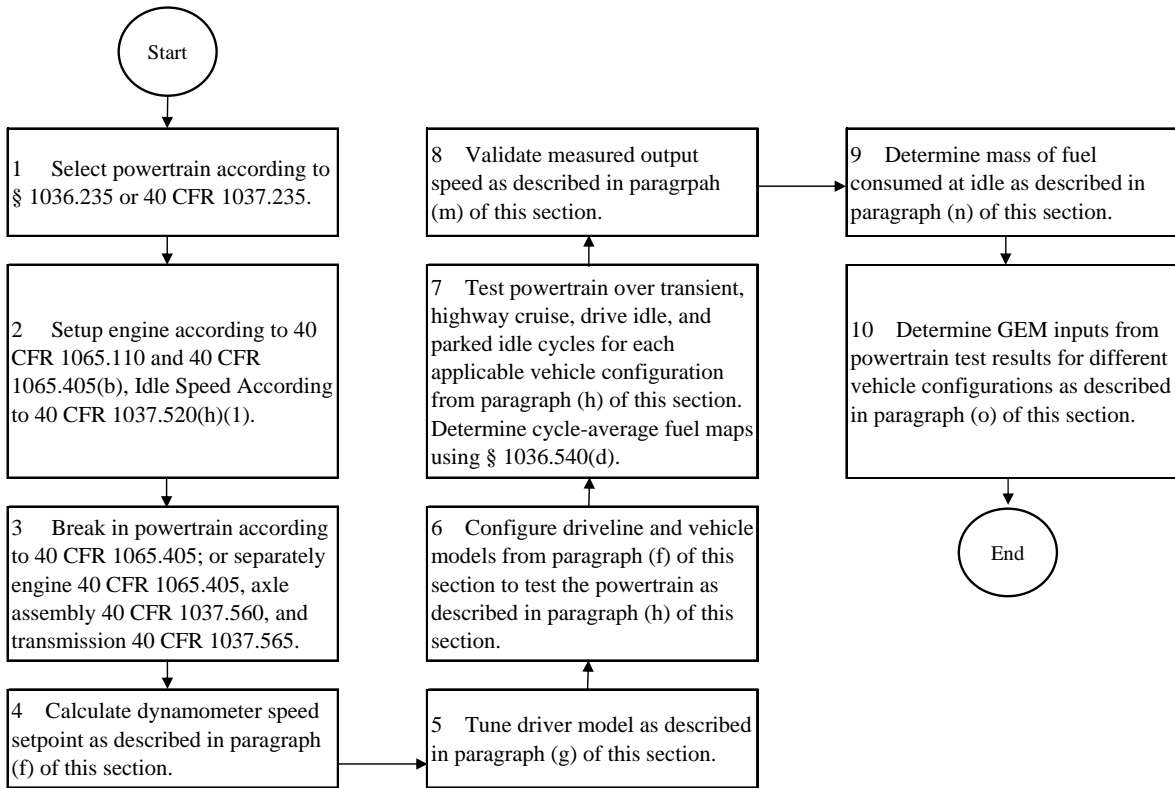
(i) Measure the voltage and current of the battery pack directly with a DC wideband power analyzer to determine power. Measure all current entering and leaving the battery pack. Do not measure voltage upstream of this measurement point. The maximum

integration period for determining amp-hours is 0.05 seconds. The power analyzer must have an accuracy for measuring current and voltage of 1 % of point or 0.3 % of maximum, whichever is greater. The power analyzer must not be susceptible to offset errors while measuring current.

(ii) If safety considerations do not allow for measuring voltage, you may determine the voltage directly from the powertrain ECM.

(11) The following figure provides an overview of the steps involved in carrying out testing under this section:

**FIGURE 1 TO PARAGRAPH (a)(11) OF § 1036.545—OVERVIEW OF POWERTRAIN TESTING**



Duty Cycle Exceptions	Note
SET, FTP, LLC	1) Do not compensate the duty cycle for the distance driven in step 5 2) Disregard duty cycles in step 7. 3) For cycles that begin with idle, leave the transmission in neutral or park for the full initial idle segment. Place the transmission into drive no earlier than 5 seconds before the first nonzero vehicle speed setpoint. 4) Use the vehicle parameters in § 1036.505(b)(2)(i) to (ix) to define the vehicle model in § 1036.545(a)(3)
SET Specific	1) For SET testing only, place the transmission into park or neutral when the cycle reaches the final idle segment. 2) Select the transmission from Table 1 of § 1036.540, substituting “engine” for “vehicle” and “highway cruise cycle” for “SET”.
FTP Specific	1) Replace Pconrated with Prated, which is the peak rated power determined in § 1036.527 2) Keep the transmission in drive for all idle segments after the initial idle segment 3) For hybrid engines, select the transmission from Table 1 of § 1036.540, substituting “engine” for “vehicle”. 4) For hybrid engines, you may request to change the engine-commanded torque at idle to better represent curb idle transmission torque (CITT)
LLC Specific	1) Replace Pconrated with Prated, which is the peak rated power determined in § 1036.527. 2) Keep the transmission in drive for all idle segments 200 seconds or less. For idle segments more than 200 seconds, place the transmission in park or neutral at the start of the idle segment and place the transmission into drive again no earlier than 5 seconds before the first nonzero vehicle speed setpoint. 3) For hybrid engines, you may request to change the engine-commanded torque at idle to better represent curb idle transmission torque (CITT). 4) For plug-in hybrid engines and powertrains, determine criteria pollutant and greenhouse gas emissions as described in § 1036.505(d) and (e), replacing “SET” with “LLC”.

(b) Test configuration. Select a powertrain for testing as described in 40 CFR 1037.235 or § 1036.235 as applicable. Set up the engine according to 40 CFR 1065.110 and 40 CFR 1065.405(b). Set the engine's idle speed to idle speed defined in 40 CFR 1037.520(h)(1).

(1) The default test configuration consists of a powertrain with all components upstream of the axle. This involves connecting the powertrain's output shaft directly to the dynamometer or to a gear box with a fixed gear ratio and measuring torque at the axle input shaft. You may instead set up the dynamometer to connect at the wheel hubs and measure torque at that location. The preceding sentence may apply if your powertrain configuration requires it, such as for hybrid powertrains or if you want to represent the axle performance with powertrain test results. Alternately you may test the powertrain with a chassis dynamometer as long as you measure speed and torque at the powertrain's output shaft or wheel hubs.

(2) For testing hybrid engines, connect the engine's crankshaft directly to the dynamometer and measure torque at that location.

(c) Powertrain temperatures during testing. Cool the powertrain during testing so temperatures for oil, coolant, block, head, transmission, battery, and power electronics are within the manufacturer's expected ranges for normal operation. You may use electronic control module outputs to comply with this paragraph (c). You may use auxiliary coolers and fans.

(d) Engine break in. Break in the engine according to 40 CFR 1065.405, the axle assembly according to 40 CFR 1037.560, and the transmission according to 40 CFR 1037.565. You may instead break in the powertrain as a complete system using the engine break in procedure in 40 CFR 1065.405.

(e) Dynamometer setup. Set the dynamometer to operate in speed-control mode (or torque-control mode for hybrid engine testing at idle, including idle portions of transient duty cycles). Record data as described in 40 CFR 1065.202. Command and control the dynamometer speed at a minimum of 5 Hz, or 10 Hz for testing hybrid engines. Run the vehicle model to calculate the dynamometer setpoints at a rate of at least 100 Hz. If the dynamometer's command frequency is less than the vehicle model dynamometer setpoint frequency, subsample the calculated setpoints for commanding the dynamometer setpoints.

(f) Driveline and vehicle model. Use the GEM HIL model's driveline and vehicle submodels or the equations in this paragraph (f) to calculate the dynamometer speed setpoint,  $f_{nref,dyno}$ , based on the torque measurement location. For all powertrains, configure GEM with the accessory load set to zero. For hybrid engines, configure GEM with the applicable accessory load as specified in §§ 1036.505 and 1036.514. For all powertrains and hybrid engines, configure GEM with the tire slip model disabled.

(1) Driveline model with a transmission in hardware. For testing with torque measurement at the axle input shaft or wheel hubs, calculate,  $f_{nref,dyno}$ , using the GEM HIL model's driveline submodel or the following equation:

$$f_{nrefi,dyno} = \frac{k_{a[speed]} \cdot v_{refi}}{2 \cdot \pi \cdot r_{[speed]}}$$

Eq. 1036.545-1

Where:

$k_{a[speed]}$  = drive axle ratio as determined in paragraph (h) of this section. Set  $k_{a[speed]}$  equal to 1.0 if torque is measured at the wheel hubs.

$v_{refi}$  = simulated vehicle reference speed as calculated in paragraph (f)(3) of this section.

$r_{[speed]}$  = tire radius as determined in paragraph (h) of this section.

(2) Driveline model with a simulated transmission. For testing with the torque measurement at the engine's crankshaft,  $f_{nref,dyno}$  is the dynamometer target speed from the GEM HIL



model's transmission submodel. You may request our approval to change the transmission submodel, as long as the changes do not affect the gear selection logic. Before testing, initialize the transmission model with the engine's measured torque curve and the applicable steady-state fuel map from the GEM HIL model. You may request our approval to input your own steady-state fuel map. For example, this request for approval could include using a fuel map that represents the combined performance of the engine and hybrid components. Configure the torque converter to simulate neutral idle when using this procedure to generate engine fuel maps in § 1036.505 or to perform the Supplemental Emission Test (SET) testing under § 1036.510. You may change engine commanded torque at idle to better represent CITT for transient testing under § 1036.512. You may change the simulated engine inertia to match the inertia of the engine under test. We will evaluate your requests under this paragraph (f)(2) based on your demonstration that that the adjusted testing better represents in-use operation.

(i) The transmission submodel needs the following model inputs:

(A) Torque measured at the engine's crankshaft.

(B) Engine estimated torque determined from the electronic control module or by converting the instantaneous operator demand to an instantaneous torque in N·m.

(C) Dynamometer mode when idling (speed-control or torque-control).

(D) Measured engine speed when idling.

(E) Transmission output angular speed,  $f_{ni,transmission}$ , calculated as follows:

$$f_{ni,transmission} = \frac{k_{a[speed]} \cdot v_{refi}}{2 \cdot \pi \cdot r_{[speed]}}$$

Eq. 1036.545-2

Where:

$k_{a[speed]}$  = drive axle ratio as determined in paragraph (h) of this section.

$v_{refi}$  = simulated vehicle reference speed as calculated in paragraph (f)(3) of this section.

$r_{[speed]}$  = tire radius as determined in paragraph (h) of this section.

(ii) The transmission submodel generates the following model outputs:

(A) Dynamometer target speed.

(B) Dynamometer idle load.

(C) Transmission engine load limit.

(D) Engine speed target.

(3) Vehicle model. Calculate the simulated vehicle reference speed,  $v_{refi}$ , using the GEM HIL model's vehicle submodel or the equations in this paragraph (f)(3):

$$v_{refi} = \left( \frac{k_a \cdot T_{i-1} \cdot (Eff_{axle}) - \left( M \cdot g \cdot C_{rr} \cdot \cos(\text{atan}(G_{i-1})) + \frac{\rho \cdot C_d A}{2} \cdot v_{ref,i-1}^2 \right) - F_{brake,i-1} - F_{grade,i-1}}{M + M_{rotating}} + v_{ref,i-1} \right)$$

Eq. 1036.545-3

Where:

$i$  = a time-based counter corresponding to each measurement during the sampling period.

Let  $v_{ref1} = 0$ ; start calculations at  $i = 2$ . A 10-minute sampling period will generally involve 60,000 measurements.

$T$  = instantaneous measured torque at the axle input, measured at the wheel hubs, or simulated by the GEM HIL model's transmission submodel. For configurations with multiple torque measurements, for example when measuring torque at the wheel hubs,  $T$  is the sum of all torque measurements.

$Eff_{axle}$  = axle efficiency. Use  $Eff_{axle} = 0.955$  for  $T \geq 0$ , and use  $Eff_{axle} = 1/0.955$  for  $T < 0$ . Use  $Eff_{axle} = 1.0$  if torque is measured at the wheel hubs.

$M$  = vehicle mass for a vehicle class as determined in paragraph (h) of this section.

$g$  = gravitational constant = 9.80665 m/s<sup>2</sup>.

$C_{rr}$  = coefficient of rolling resistance for a vehicle class as determined in paragraph (h) of this section.

$G_{i-1}$  = the percent grade interpolated at distance,  $D_{i-1}$ , from the duty cycle in appendix D to this part corresponding to measurement ( $i-1$ ).

$$D_{i-1} = \sum_{i=1}^N (v_{ref,i-1} \cdot \Delta t_{i-1})$$

Eq. 1036.545-4

$\rho$  = air density at reference conditions. Use  $\rho = 1.1845$  kg/m<sup>3</sup>.

$C_dA$  = drag area for a vehicle class as determined in paragraph (h) of this section.

$F_{brake,i-1}$  = instantaneous braking force applied by the driver model.

$F_{grade,i-1} = M \cdot g \cdot \sin(\text{atan}(G_{i-1}))$

Eq. 1036.545-5

$\Delta t$  = the time interval between measurements. For example, at 100 Hz,  $\Delta t = 0.0100$  seconds.

$M_{rotating}$  = inertial mass of rotating components. Let  $M_{rotating} = 340$  kg for vocational Light HDV or vocational Medium HDV. See paragraph (h) of this section for tractors and for vocational Heavy HDV.

(4) Example. The following example illustrates a calculation of  $f_{nref,dyno}$  using paragraph (f)(1) of this section where torque is measured at the axle input shaft. This example is for a vocational Light HDV or vocational Medium HDV with 6 speed automatic transmission at B speed (Test 4 in Table 1 to paragraph (h)(2)(ii) of this section).

$k_{aB} = 4.0$

$r_B = 0.399$  m

$T_{999} = 500.0$  N·m

$C_{rr} = 7.7$  N/kN =  $7.7 \cdot 10^{-3}$  N/N

$M = 11408$  kg

$C_dA = 5.4$  m<sup>2</sup>

$G_{999} = 0.39$  % = 0.0039

$$D_{999} = \sum_{i=0}^{998} (19.99 \cdot 0.01 + 20.0 \cdot 0.01 + \dots + v_{ref,998} \cdot \Delta t_{998}) = 1792 \text{ m}$$

$F_{brake,999} = 0$  N

$v_{ref,999} = 20.0$  m/s

$F_{grade,999} = 11408 \cdot 9.81 \cdot \sin(\text{atan}(0.0039)) = 436.5$  N

$\Delta t = 0.0100$  s

$M_{rotating} = 340$  kg

$$v_{\text{ref1000}} = \left( \frac{4.0 \cdot 500.0}{0.399} \cdot (0.955) - \left( 11408 \cdot 9.80665 \cdot 7.7 \cdot 10^{-3} \cdot \cos(\text{atan}(0.0039)) + \frac{1.1845 \cdot 5.4}{2} \cdot 20.0^2 \right) - 0 - 436.5 \right) \cdot \frac{0.0100}{11408 + 340} + 20.0 v_{\text{ref1000}}$$

$$v_{\text{ref1000}} = 20.00189 \text{ m/s}$$

$$f_{\text{nref1000,dyno}} = \frac{4.0 \cdot 20.00189}{2 \cdot 3.14 \cdot 0.399}$$

$$f_{\text{nref1000,dyno}} = 31.93 \text{ r/s} = 1915.8 \text{ r/min}$$

(g) Driver model. Use the GEM HIL model's driver submodel or design a driver model to simulate a human driver modulating the throttle and brake pedals. In either case, tune the model to follow the test cycle as closely as possible meeting the following specifications:

(1) The driver model must meet the following speed requirements:

(i) For operation over the highway cruise cycles, the speed requirements described in 40 CFR 1066.425(b) and (c).

(ii) For operation over the transient cycle specified in appendix A of this part, the SET as defined § 1036.510, the Federal Test Procedure (FTP) as defined in § 1036.512, and the Low Load Cycle (LLC) as defined in § 1036.514, the speed requirements described in 40 CFR 1066.425(b) and (c).

(iii) The exceptions in 40 CFR 1066.425(b)(4) apply to the highway cruise cycles, the transient cycle specified in appendix A of this part, SET, FTP, and LLC.

(iv) If the speeds do not conform to these criteria, the test is not valid and must be repeated.

(2) Send a brake signal when operator demand is zero and vehicle speed is greater than the reference vehicle speed from the test cycle. Include a delay before changing the brake signal to prevent dithering, consistent with good engineering judgment.

(3) Allow braking only if operator demand is zero.

(4) Compensate for the distance driven over the duty cycle over the course of the test. Use the following equation to perform the compensation in real time to determine your time in the cycle:

$$t_{\text{cycle}i} = \sum_{i=1}^N \left( \left( \frac{v_{\text{vehicle},i-1}}{v_{\text{cycle},i-1}} \right) \cdot \Delta t_{i-1} \right)$$

Eq. 1036.545-6

Where:

$v_{\text{vehicle}}$  = measured vehicle speed.

$v_{\text{cycle}}$  = reference speed from the test cycle. If  $v_{\text{cycle},i-1} < 1.0$  m/s, set  $v_{\text{cycle},i-1} = v_{\text{vehicle},i-1}$ .

(h) Vehicle configurations to evaluate for generating fuel maps as defined in § 1036.505.

Configure the driveline and vehicle models from paragraph (f) of this section in the test cell to test the powertrain. Simulate multiple vehicle configurations that represent the range of intended vehicle applications using one of the following options:

(1) For known vehicle configurations, use at least three equally spaced axle ratios or tire sizes and three different road loads (nine configurations), or at least four equally spaced axle ratios or tire sizes and two different road loads (eight configurations). Select axle ratios to

represent the full range of expected vehicle installations. Select axle ratios and tire sizes such that the ratio of engine speed to vehicle speed covers the range of ratios of minimum and maximum engine speed to vehicle speed when the transmission is in top gear for the vehicles in which the powertrain will be installed. Note that you do not have to use the same axle ratios and tire sizes for each GEM regulatory subcategory. You may determine appropriate  $C_{rr}$ ,  $C_{dA}$ , and mass values to cover the range of intended vehicle applications or you may use the  $C_{rr}$ ,  $C_{dA}$ , and mass values specified in paragraph (h)(2) of this section.

(2) If vehicle configurations are not known, determine the vehicle model inputs for a set of vehicle configurations as described in § 1036.540(c)(3) with the following exceptions:

(i) In the equations of § 1036.540(c)(3)(i),  $k_{topgear}$  is the actual top gear ratio of the powertrain instead of the transmission gear ratio in the highest available gear given in Table 1 in § 1036.540.

(ii) Test at least eight different vehicle configurations for powertrains that will be installed in Spark-ignition HDE, vocational Light HDV, and vocational Medium HDV using the following table instead of Table 2 in § 1036.540:

**TABLE 1 TO PARAGRAPH (h)(2)(ii) OF § 1036.545—VEHICLE CONFIGURATIONS FOR TESTING SPARK-IGNITION HDE, LIGHT HDE, AND MEDIUM HDE**

<b>Parameter</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>
$C_{rr}$ (N/kN)	6.2	7.7	6.2	7.7	6.2	7.7	6.2	7.7
$C_{dA}$	3.4	5.4	3.4	5.4	3.4	5.4	3.4	5.4
CI engine speed for $\frac{f_{ntire}}{v_{vehicle}}$ and $k_a$	$f_{nrefA}$	$f_{nrefA}$	$f_{nrefB}$	$f_{nrefB}$	$f_{nrefC}$	$f_{nrefC}$	$f_{ntest}$	$f_{ntest}$
SI engine speed for $\frac{f_{ntire}}{v_{vehicle}}$ and $k_a$	$f_{nrefD}$	$f_{nrefD}$	$f_{nrefA}$	$f_{nrefA}$	$f_{nrefB}$	$f_{nrefB}$	$f_{nrefC}$	$f_{nrefC}$
$M$ (kg)	7,257	11,408	7,257	11,408	7,257	11,408	7,257	11,408
$M_{rotating}$ (kg)	340	340	340	340	340	340	340	340
Drive axle configuration <sup>a</sup>	4x2	4x2	4x2	4x2	4x2	4x2	4x2	4x2
GEM regulatory subcategory <sup>a</sup>	LHD	MHD	LHD	MHD	LHD	MHD	LHD	MHD

<sup>a</sup>Drive axle configuration and GEM regulatory subcategory are not used if using the equations in paragraph (f)(3) of this section.

(iii) Select and test vehicle configurations as described in § 1036.540(c)(3)(iii) for powertrains that will be installed in vocational Heavy HDV and tractors using the following tables instead of Table 3 and Table 4 in § 1036.540:

**TABLE 2 TO PARAGRAPH (h)(2)(iii) OF § 1036.545—VEHICLE CONFIGURATIONS FOR TESTING GENERAL PURPOSE TRACTORS AND VOCATIONAL HEAVY HDV**

<b>Parameter</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>
$C_{rr}$ (N/kN)	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>
$C_{dA}$	<u>5.4</u>	<u>4.7</u>	<u>4.0</u>	<u>5.4</u>	<u>4.7</u>	<u>4.0</u>	<u>5.4</u>	<u>4.7</u>	<u>4.0</u>
Engine speed for $\frac{f_{ntire}}{v_{vehicle}}$ and $k_a$	$f_{nrefD}$	$f_{nrefD}$	$f_{nrefD}$	$f_{nrefB}$	$f_{nrefB}$	$f_{nrefB}$	$f_{ntest}$	$f_{ntest}$	$f_{ntest}$
$M$ (kg)	<u>31,978</u>	<u>25,515</u>	<u>19,051</u>	<u>31,978</u>	<u>25,515</u>	<u>19,051</u>	<u>31,978</u>	<u>25,515</u>	<u>19,051</u>
$M_{rotating}$ (kg)	<u>1,021</u>	<u>794</u>	<u>794</u>	<u>1,021</u>	<u>794</u>	<u>794</u>	<u>1,021</u>	<u>794</u>	<u>794</u>
Drive axle configuration <sup>a</sup>	<u>6x4</u>	<u>6x4</u>	<u>4x2</u>	<u>6x4</u>	<u>6x4</u>	<u>4x2</u>	<u>6x4</u>	<u>6x4</u>	<u>4x2</u>
GEM regulatory subcategory <sup>a</sup>	<u>C8_SC</u> <u>HR</u>	<u>C8_DC</u> <u>MR</u>	<u>C7_DC</u> <u>MR</u>	<u>C8_SC</u> <u>HR</u>	<u>C8_DC</u> <u>MR</u>	<u>C7_DC</u> <u>MR</u>	<u>C8_SC</u> <u>HR</u>	<u>C8_DC</u> <u>MR</u>	<u>C7_DC</u> <u>MR</u>
Vehicle weight reduction (lbs)	<u>0</u>	<u>13,275</u>	<u>6,147</u>	<u>0</u>	<u>13,275</u>	<u>6,147</u>	<u>0</u>	<u>13,275</u>	<u>6,147</u>

<sup>a</sup>Drive axle configuration and GEM regulatory subcategory are not used if using the equations in paragraph (f)(3) of this section.

**TABLE 3 TO PARAGRAPH (h)(2)(iii) OF § 1036.545—VEHICLE CONFIGURATIONS FOR TESTING HEAVY HDE INSTALLED IN HEAVY-HAUL TRACTORS**

<b>Parameter</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
$C_{rr}$ (N/kN)	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>	<u>6.9</u>
$C_{dA}$	<u>5.0</u>	<u>5.4</u>	<u>5.0</u>	<u>5.4</u>	<u>5.0</u>	<u>5.4</u>
Engine speed for $\frac{f_{ntire}}{v_{vehicle}}$ and $k_a$	$f_{nrefD}$	$f_{nrefD}$	$f_{nrefB}$	$f_{nrefB}$	$f_{ntest}$	$f_{ntest}$
$M$ (kg)	<u>53,751</u>	<u>31,978</u>	<u>53,751</u>	<u>31,978</u>	<u>53,751</u>	<u>31,978</u>
$M_{rotating}$ (kg)	<u>1,021</u>	<u>1,021</u>	<u>1,021</u>	<u>1,021</u>	<u>1,021</u>	<u>1,021</u>
Drive axle configuration <sup>a</sup>	<u>6x4</u>	<u>6x4</u>	<u>6x4</u>	<u>6x4</u>	<u>6x4</u>	<u>6x4</u>
GEM regulatory subcategory <sup>a</sup>	<u>C8_HH</u>	<u>C8_SC HR</u>	<u>C8_HH</u>	<u>C8_SC HR</u>	<u>C8_HH</u>	<u>C8_SC HR</u>

<sup>a</sup>Drive axle configuration and GEM regulatory subcategory are not used if using the equations in paragraph (f)(3) of this section.

(3) For hybrid powertrain systems where the transmission will be simulated, use the transmission parameters defined in § 1036.540(c)(2) to determine transmission type and gear ratio. Use a fixed transmission efficiency of 0.95. The GEM HIL transmission model uses a transmission parameter file for each test that includes the transmission type, gear ratios, lockup gear, torque limit per gear from § 1036.540(c)(2), and the values from § 1036.505(b)(4) and (c).

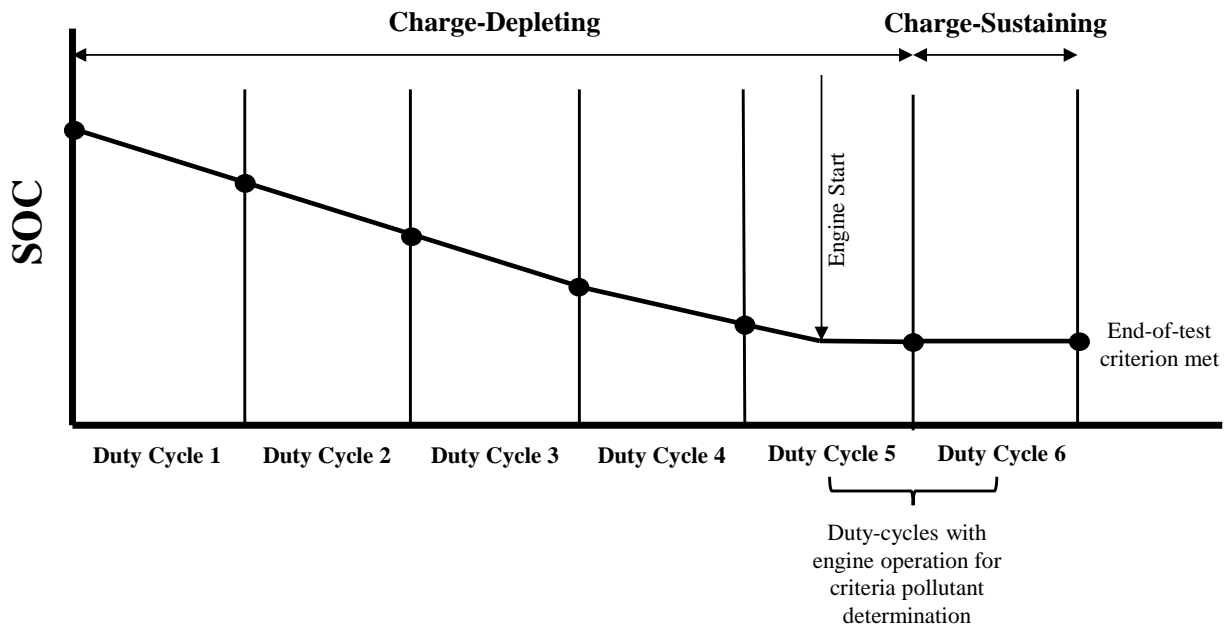
(i) [Reserved]

(j) *Duty cycles to evaluate.* Operate the powertrain over each of the duty cycles specified in 40 CFR 1037.510(a)(2), and for each applicable vehicle configuration from paragraph (h) of this section. Determine cycle-average powertrain fuel maps by testing the powertrain using the procedures in § 1036.540(d) with the following exceptions:

- (1) Understand “engine” to mean “powertrain”.
- (2) Warm up the powertrain as described in § 1036.520(c)(1).

- (3) Within 90 seconds after concluding the warm-up, start the transition to the preconditioning cycle as described in paragraph (j)(5) of this section.
- (4) For plug-in hybrid engines, precondition the battery and then complete all back-to-back tests for each vehicle configuration according to 40 CFR 1066.501 before moving to the next vehicle configuration. Figure 2 of this section provides an example of a charge-depleting test sequence where there are two test intervals that contain engine operation. Figure 2 follows:

FIGURE 2 TO PARAGRAPH (j)(4) OF § 1036.545— GENERIC DUTY-CYCLE CYCLE CHARGE-DEPLETING TEST SEQUENCE



- (5) If the preceding duty cycle does not end at 0 mi/hr, transition between duty cycles by decelerating at a rate of 2 mi/hr/s at 0 % grade until the vehicle reaches zero speed. Shut off the powertrain. Prepare the powertrain and test cell for the next duty-cycle.
- (6) Start the next duty-cycle within 60 to 180 seconds after shutting off the powertrain.
- (i) To start the next duty-cycle, for hybrid powertrains, key on the vehicle and then start the duty-cycle. For conventional powertrains key on the vehicle, start the engine, wait for the engine to stabilize at idle speed, and then start the duty-cycle.
- (ii) If the duty-cycle does not start at 0 mi/hr, transition to the next duty cycle by accelerating at a target rate of 1 mi/hr/s at 0 % grade. Stabilize for 10 seconds at the initial duty cycle conditions and start the duty-cycle.
- (7) Calculate cycle work using GEM or the speed and torque from the driveline and vehicle models from paragraph (f) of this section to determine the sequence of duty cycles.
- (8) Calculate the mass of fuel consumed for idle duty cycles as described in paragraph (n) of this section.
- (k) Measuring NO<sub>x</sub> emissions. Measure NO<sub>x</sub> emissions for each sampling period in grams. You may perform these measurements using a NO<sub>x</sub> emission-measurement system that meets the requirements of 40 CFR part 1065, subpart J. If a system malfunction prevents you from measuring NO<sub>x</sub> emissions during a test under this section but the test otherwise gives valid results, you may consider this a valid test and omit the NO<sub>x</sub> emission measurements; however,

we may require you to repeat the test if we determine that you inappropriately voided the test with respect to NO<sub>x</sub> emission measurement.

(l) [Reserved]

(m) Measured output speed validation. For each test point, validate the measured output speed(s) with the corresponding reference values. For test setups where speed is measured at multiple locations, each location must meet the requirements in this paragraph (m). If the range of reference speed is less than 10 percent of the mean reference speed, you need to meet only the standard error of the estimate in Table 1 of this section. You may delete points when the vehicle is stopped. If your speed measurement is not at the location of  $f_{nref}$ , correct your measured speed using the constant speed ratio between the two locations. Apply cycle-validation criteria for each separate transient or highway cruise cycle based on the following parameters:

TABLE 4 TO PARAGRAPH (m) OF § 1036.545 – STATISTICAL CRITERIA FOR VALIDATING DUTY CYCLES

<u>Parameter<sup>a</sup></u>	<u>Speed Control</u>
<u>Slope, <math>a_1</math></u>	<u><math>0.990 \leq a_1 \leq 1.010</math>.</u>
<u>Absolute value of intercept, <math> a_0 </math></u>	<u><math>\leq 2.0</math> % of maximum <math>f_{nref}</math> speed.</u>
<u>Standard error of the estimate, <math>SEE</math></u>	<u><math>\leq 2.0</math> % of maximum <math>f_{nref}</math> speed.</u>
<u>Coefficient of determination, <math>r^2</math></u>	<u><math>\geq 0.990</math>.</u>

<sup>a</sup>Determine values for specified parameters as described in 40 CFR 1065.514(e) by comparing measured and reference values for  $f_{nref,dyno}$ .

(n) Fuel consumption at idle. Record measurements using direct and/or indirect measurement of fuel flow. Determine the fuel-consumption rates at idle for the applicable duty cycles described in 40 CFR 1037.510(a)(2) as follows:

(1) Direct fuel flow measurement. Determine the corresponding mean values for mean idle fuel mass flow rate,  $\bar{m}_{fuelidle}$ , for each duty cycle, as applicable. Use of redundant direct fuel-flow measurements require our advance approval.

(2) Indirect fuel flow measurement. Record speed and torque and measure emissions and other inputs needed to run the chemical balance in 40 CFR 1065.655(c). Determine the corresponding mean values for each duty cycle. Use of redundant indirect fuel-flow measurements require our advance approval. Measure background concentration as described in § 1036.535(b)(4)(ii). We recommend setting the CVS flow rate as low as possible to minimize background, but without introducing errors related to insufficient mixing or other operational considerations. Note that for this testing 40 CFR 1065.140(e) does not apply, including the minimum dilution ratio of 2:1 in the primary dilution stage. Calculate the idle fuel mass flow rate for each duty cycle,  $\bar{m}_{fuelidle}$ , for each set of vehicle settings, as follows:

$$\bar{m}_{fuelidle} = \frac{M_C}{w_{Cmeas}} \cdot \left( \bar{n}_{exh} \cdot \frac{\bar{x}_{Ccombdry}}{1 + \bar{x}_{H2Oexhdry}} - \frac{\bar{m}_{CO2DEF}}{M_{CO2}} \right)$$

Eq. 1036.545-7

Where:

$M_C$  = molar mass of carbon.

$w_{C_{meas}}$  = carbon mass fraction of fuel (or mixture of test fuels) as determined in 40 CFR 1065.655(d), except that you may not use the default properties in Table 2 of 40 CFR 1065.655 to determine  $\alpha$ ,  $\beta$ , and  $w_C$  for liquid fuels.

$\bar{n}_{exh}$  = the mean raw exhaust molar flow rate from which you measured emissions according to 40 CFR 1065.655.

$\bar{x}_{C_{combdry}}$  = the mean concentration of carbon from fuel and any injected fluids in the exhaust per mole of dry exhaust.

$\bar{x}_{H_2O_{exhdry}}$  = the mean concentration of H<sub>2</sub>O in exhaust per mole of dry exhaust.

$\bar{m}_{CO_2DEF}$  = the mean CO<sub>2</sub> mass emission rate resulting from diesel exhaust fluid decomposition over the duty cycle as determined in § 1036.535(b)(9). If your engine does not use diesel exhaust fluid, or if you choose not to perform this correction, set  $\bar{m}_{CO_2DEF}$  equal to 0.

$M_{CO_2}$  = molar mass of carbon dioxide.

*Example:*

$M_C = 12.0107$  g/mol

$w_{C_{meas}} = 0.867$

$\bar{n}_{exh} = 25.534$  mol/s

$\bar{x}_{C_{combdry}} = 2.805 \cdot 10^{-3}$  mol/mol

$\bar{x}_{H_2O_{exhdry}} = 3.53 \cdot 10^{-2}$  mol/mol

$\bar{m}_{CO_2DEF} = 0.0726$  g/s

$M_{CO_2} = 44.0095$

$$\bar{m}_{fuelidle} = \frac{12.0107}{0.867} \cdot \left( 25.534 \cdot \frac{2.805 \cdot 10^{-3}}{1 + 3.53 \cdot 10^{-2}} - \frac{0.0726}{44.0095} \right)$$

$\bar{m}_{fuelidle} = 0.405$  g/s = 1458.6 g/hr

(o) *Create GEM inputs.* Use the results of powertrain testing to determine GEM inputs for the different simulated vehicle configurations as follows:

(1) Correct the measured or calculated fuel masses,  $m_{fuel[cycle]}$ , and mean idle fuel mass flow rates,  $\bar{m}_{fuelidle}$ , if applicable, for each test result to a mass-specific net energy content of a reference fuel as described in § 1036.535(e), replacing  $\bar{m}_{fuel}$  with  $m_{fuel[cycle]}$  where applicable in Eq. 1036.535-4.

(2) Declare fuel masses,  $m_{fuel[cycle]}$  and  $\bar{m}_{fuelidle}$ . Determine  $m_{fuel[cycle]}$  using the calculated fuel mass consumption values described in § 1036.540(d)(12). In addition, declare mean fuel mass flow rate for each applicable idle duty cycle,  $\bar{m}_{fuelidle}$ . These declared values may not be lower than any corresponding measured values determined in this section. If you use both direct and indirect measurement of fuel flow, determine the corresponding declared values as described in § 1036.535(g)(2) and (3). These declared values, which serve as emission standards, collectively represent the powertrain fuel map for certification.

(3) For engines designed for plug-in hybrid electric vehicles, the mass of fuel for each cycle,  $m_{fuel[cycle]}$ , is the utility factor-weighted fuel mass,  $m_{fuelUF[cycle]}$ . This is determined by calculating  $m_{fuel}$  for the full charge-depleting and charge-sustaining portions of the test and weighting the results, using the following equation:

$$m_{fuelUF[cycle]} = \sum_{i=1}^N [m_{fuel[cycle]CDi} \cdot (UF_{DCDi} - UF_{DCDi-1})] + \sum_{j=1}^M [m_{fuel[cycle]CSj}] \cdot \frac{(1 - UF_{RCD})}{M}$$

Eq. 1036.545-8



Where:

$i$  = an indexing variable that represents one test interval.

$N$  = total number of charge-depleting test intervals.

$m_{\text{fuel[cycle]CD}i}$  = total mass of fuel in the charge-depleting portion of the test for each test interval,  $i$ , starting from  $i = 1$ , including the test interval(s) from the transition phase.

$UF_{\text{DCD}i}$  = utility factor fraction at distance  $D_{\text{CD}i}$  from Eq. 40 CFR 1037.505-9 as determined by interpolating the approved utility factor curve for each test interval,  $i$ , starting from  $i = 1$ .

Let  $UF_{\text{DCD}0} = 0$

$j$  = an indexing variable that represents one test interval.

$M$  = total number of charge-sustaining test intervals.

$m_{\text{fuel[cycle]CS}j}$  = total mass of fuel over the charge-sustaining portion of the test for each test interval,  $j$ , starting from  $j = 1$ .

$UF_{\text{RCD}}$  = utility factor fraction at the full charge-depleting distance,  $R_{\text{CD}}$ , as determined by interpolating the approved utility factor curve.  $R_{\text{CD}}$  is the cumulative distance driven over  $N$  charge-depleting test intervals.

$$D_{\text{CD}i} = \sum_{k=1}^Q (v_k \cdot \Delta t)$$

Eq. 1036.545-9

Where:

$k$  = an indexing variable that represents one recorded velocity value.

$Q$  = total number of measurements over the test interval.

$v$  = vehicle velocity at each time step,  $k$ , starting from  $k = 1$ . For tests completed under this section,  $v$  is the vehicle velocity as determined by Eq. 1036.545-1. Note that this should include charge-depleting test intervals that start when the engine is not yet operating.

$\Delta t = 1/f_{\text{record}}$

$f_{\text{record}}$  = the record rate.

Example for the 55 mi/hr cruise cycle:

$Q = 8790$

$v_1 = 55.0$  mi/hr

$v_2 = 55.0$  mi/hr

$v_3 = 55.1$  mi/hr

$f_{\text{record}} = 10$  Hz

$\Delta t = 1/10$  Hz = 0.1 s

$$D_{\text{CD}1} = \sum_{k=1}^{8790} (55.0 \cdot 0.1 + 55.0 \cdot 0.1 + 55.1 \cdot 0.1 + v_{8790} \cdot \Delta t) = 13.4 \text{ mi}$$

$D_{\text{CD}2} = 13.4$  mi

$D_{\text{CD}3} = 13.4$  mi

$N = 3$

$UF_{\text{DCD}1} = 0.05$

$UF_{\text{DCD}2} = 0.11$

$UF_{\text{DCD}3} = 0.21$

$m_{\text{fuel55cruiseCD}1} = 0$  g

$m_{\text{fuel55cruiseCD}2} = 0$  g

$$m_{\text{fuel55cruiseCD3}} = 1675.4 \text{ g}$$

$$M = 1$$

$$m_{\text{fuel55cruiseCS}} = 4884.1 \text{ g}$$

$$UF_{\text{RCD}} = 0.21$$

$$m_{\text{fuelUF55cruise}} = \frac{[0 \cdot (0.05 - 0) + 0 \cdot (0.11 - 0.05) + 1675.4 \cdot (0.21 - 0.11)] + 4884.1}{(1 - 0.21)}$$

$$m_{\text{fuelUF55cruise}} = 4026.0 \text{ g}$$

(4) For the transient cycle specified in 40 CFR 1037.510(a)(2)(i), calculate powertrain output

speed per unit of vehicle speed,  $\left[ \frac{\bar{f}_{\text{powertrain}}}{\bar{v}_{\text{powertrain}}} \right]_{\text{[cycle]}}$ , using one of the following methods:

(i) For testing with torque measurement at the axle input shaft:

$$\left[ \frac{\bar{f}_{\text{powertrain}}}{\bar{v}_{\text{powertrain}}} \right]_{\text{[cycle]}} = \frac{k_a}{2 \cdot \pi \cdot r_{\text{[speed]}}}$$

Eq. 1036.545-10

Example:

$$k_a = 4.0$$

$$r_B = 0.399 \text{ m}$$

$$\left[ \frac{\bar{f}_{\text{powertrain}}}{\bar{v}_{\text{powertrain}}} \right]_{\text{transienttest4}} = \frac{4.0}{2 \cdot 3.14 \cdot 0.399}$$

$$\left[ \frac{\bar{f}_{\text{powertrain}}}{\bar{v}_{\text{powertrain}}} \right]_{\text{transienttest4}} = 1.596 \text{ r/m}$$

(ii) For testing with torque measurement at the wheel hubs, use Eq. 1036.545-8 setting  $k_a$  equal to 1.

(iii) For testing with torque measurement at the engine's crankshaft:

$$\left[ \frac{\bar{f}_{\text{powertrain}}}{\bar{v}_{\text{powertrain}}} \right]_{\text{[cycle]}} = \frac{\bar{f}_{\text{engine}}}{\bar{v}_{\text{ref}}}$$

Eq. 1036.545-11

Where:

$\bar{f}_{\text{engine}}$  = average engine speed when vehicle speed is at or above 0.100 m/s.

$\bar{v}_{\text{ref}}$  = average simulated vehicle speed at or above 0.100 m/s.

Example:

$$\bar{f}_{\text{engine}} = 1870 \text{ r/min} = 31.17 \text{ r/s}$$

$$\bar{v}_{\text{ref}} = 19.06 \text{ m/s}$$

$$\left[ \frac{\bar{f}_{\text{powertrain}}}{\bar{v}_{\text{powertrain}}} \right]_{\text{transienttest4}} = \frac{31.17}{19.06}$$

$$\left[ \frac{\bar{f}_{\text{powertrain}}}{\bar{v}_{\text{powertrain}}} \right]_{\text{transienttest4}} = 1.635 \text{ r/m}$$

(5) Calculate engine idle speed, by taking the average engine speed measured during the transient cycle test while the vehicle speed is below 0.100 m/s. (Note: Use all the charge-sustaining test intervals when determining engine idle speed for plug-in hybrid engines and plug-in hybrid powertrains.)

(6) For the cruise cycles specified in 40 CFR 1037.510(a)(2)(ii), calculate the average powertrain output speed,  $\bar{f}_{\text{powertrain}}$ , and the average powertrain output torque (positive torque only),  $\bar{T}_{\text{powertrain}}$ , at vehicle speed at or above 0.100 m/s. (Note: Use all the charge-sustaining and charge-depleting test intervals when determining  $\bar{f}_{\text{powertrain}}$  and  $\bar{T}_{\text{powertrain}}$  for plug-in hybrid engines and plug-in hybrid powertrains.)

(7) Calculate positive work,  $W_{\text{[cycle]}}$ , as the work over the duty cycle at the axle input shaft, wheel hubs, or the engine's crankshaft, as applicable, when vehicle speed is at or above 0.100 m/s. For plug-in hybrid engines and plug-in hybrid powertrains, calculate  $W_{\text{[cycle]}}$  by calculating the positive work over each of the charge-sustaining and charge-depleting test intervals and then averaging them together. For test setups where speed and torque are measured at multiple locations, determine  $W_{\text{[cycle]}}$  by integrating the sum of the power measured at each location.

(8) The following tables illustrate the GEM data inputs corresponding to the different vehicle configurations for a given duty cycle:

(i) For the transient cycle:

TABLE 5 TO PARAGRAPH (o)(8)(i) OF § 1036.545 –EXAMPLE OF OUTPUT MATRIX FOR TRANSIENT CYCLE VEHICLE CONFIGURATIONS

<b>Parameter</b>	<b>Configuration</b>					
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>...</b>	<b>n</b>
$m_{\text{fuel[cycle]}}$						
$\left[ \begin{array}{c} \bar{f}_{\text{powertrain}} \\ \bar{v}_{\text{powertrain}} \end{array} \right]_{\text{[cycle]}}$						
$W_{\text{[cycle]}}$						
$\bar{f}_{\text{idle}}$						

(ii) For the cruise cycles:

TABLE 6 TO PARAGRAPH (o)(8)(ii) OF § 1036.545 – GENERIC EXAMPLE OF OUTPUT MATRIX FOR CRUISE CYCLE VEHICLE CONFIGURATIONS

<b>Parameter</b>	<b>Configuration</b>								
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>...</b>	<b>n</b>
$m_{\text{fuel[cycle]}}$									
$\bar{f}_{\text{powertrain[cycle]}}$									
$\bar{T}_{\text{powertrain[cycle]}}$									
$W_{\text{[cycle]}}$									

(p) Determining useable battery energy. Useable battery energy (UBE) is defined as the total DC discharge energy,  $E_{\text{DCDtotal}}$ , measured in DC Watt hours, over the charge-depleting portion of the test sequence determined in paragraph (p)(2) of this section for the Heavy-duty Transient Test Cycle in 40 CFR part 1037, appendix A. Select a representative vehicle configuration from paragraph (h) of this section for determination of UBE. UBE represents the total deliverable energy the battery is capable of providing while a powertrain is following a duty cycle on a dynamometer.

(1) Measure DC discharge energy,  $E_{DCD}$ , in watt-hours and DC discharge current per hour,  $C_D$ , for the charge-depleting portion of the test sequence. The measurement points must capture all the current flowing into and out of the battery pack during powertrain operation, including current associated with regenerative braking. The equation for calculating powertrain  $E_{DCD}$  is given in Eq. 1036.545-12, however, it is expected that this calculation will typically be performed internally by the power analyzer specified in paragraph (a)(10)(i) of this section. Battery voltage measurements made by the powertrain's own on-board sensors (such as those available via a diagnostic port) may be used for calculating  $E_{DCD}$  if these measurements are equivalent to those produced by the power analyzer.

$$E_{DCD} = \sum_{i=0}^N V_i \cdot I_i \cdot \Delta t$$

Eq. 1036.545-12

Where:

$i$  = an indexing variable that represents one individual measurement.

$N$  = total number of measurements.

$V$  = battery DC bus voltage.

$I$  = battery current.

$\Delta t = 1/f_{\text{record}}$

$f_{\text{record}}$  = the data recording frequency.

Example:

$N = 13360$

$V_1 = 454.0$

$V_2 = 454.0$

$I_1 = 0$

$I_2 = 0$

$f_{\text{record}} = 20 \text{ Hz}$

$\Delta t = 1/20 = 0.05 \text{ s}$

$$E_{DCD} = \sum_{i=0}^{13360} (454.0 \cdot 0 + 454.0 \cdot 0 + \dots + V_{13360} \cdot I_{13360}) \cdot 0.05$$

$E_{DCD} = 6540232.7 \text{ W}\cdot\text{s} = 1816.7 \text{ W}\cdot\text{hr}$

(2) Determine a declared UBE that is at or below the corresponding value determined in paragraph (p)(1) of this section, including those from redundant measurements. This declared UBE serves as the initial UBE determined under 40 CFR 1037.115(f).

30. Amend § 1036.550 by revising paragraphs (b)(1)(i), (b)(2) introductory text, and (b)(2)(i) to read as follows:

**§ 1036.550 Calculating greenhouse gas emission rates.**

\* \* \* \* \*

(b) \* \* \*

(1) \* \* \*

(i) For liquid fuels, determine  $E_{\text{mfuelmeas}}$  according to ASTM D4809 (incorporated by reference in § 1036.810). Have the sample analyzed by at least three different labs and determine the final value of your test fuel's  $E_{\text{mfuelmeas}}$  as the median of all the lab test results you obtained as described in 40 CFR 1065.602(m). If you have results from three different labs, we recommend you screen them to determine if additional observations are needed. To perform this screening, determine the absolute value of the difference between each lab result and the average of the other two lab results. If the largest of these three resulting absolute value differences is greater than 0.297 MJ/kg, we recommend you obtain additional results prior to determining the final value of  $E_{\text{mfuelmeas}}$ .

\* \* \* \* \*

(2) Determine your test fuel's carbon mass fraction,  $w_c$ , as described in 40 CFR 1065.655(d), expressed to at least three decimal places; however, you must measure fuel properties for  $\alpha$  and  $\beta$  rather than using the default values specified in Table 1 of 40 CFR 1065.655(e).

(i) For liquid fuels, have the sample analyzed by at least three different labs and determine the final value of your test fuel's  $w_c$  as the median of all of the lab results you obtained as described in 40 CFR 1065.602(m). If you have results from three different labs, we recommend you screen them to determine if additional observations are needed. To perform this screening, determine the absolute value of the difference between each lab result and the average of the other two lab results. If the largest of these three resulting absolute value differences is greater than 1.56 percent carbon, we recommend you obtain additional results prior to determining the final value of  $w_c$ .

\* \* \* \* \*

## Subpart G—Special Compliance Provisions

31. Amend § 1036.605 by revising paragraph (e) to read as follows:

### § 1036.605 Alternate emission standards for engines used in specialty vehicles.

\* \* \* \* \*

(e) In a separate application for a certificate of conformity, identify the corresponding nonroad engine family, describe the label required under section, state that you meet applicable diagnostic requirements under 40 CFR part 1039 or part 1048, and identify your projected U.S.-directed nationwide production volume.

\* \* \* \* \*

32. Amend § 1036.615 by revising paragraph (a) to read as follows:

### § 1036.615 Engines with Rankine cycle waste heat recovery and hybrid powertrains.

\* \* \* \* \*

(a) *Pre-transmission hybrid powertrains.* Test pre-transmission hybrid powertrains with the hybrid engine procedures of 40 CFR part 1065 or with the post-transmission procedures in §40 CFR 10367.5450. Pre-transmission hybrid powertrains are those engine systems that include features to recover and store energy during engine motoring operation but not from the vehicle's wheels. Engines certified with pre-transmission hybrid powertrains must be certified to meet the diagnostic requirements as specified in § 1036.110 with respect to powertrain components and systems; if different manufacturers produce the engine and the hybrid powertrain, the hybrid powertrain manufacturer may separately certify its powertrain relative to diagnostic requirements.

\* \* \* \* \*

33. Amend § 1036.630 by revising paragraph (b) to read as follows:

**§ 1036.630 Certification of engine greenhouse gas emissions for powertrain testing.**

\* \* \* \* \*

(b) If you choose to certify only fuel map emissions for an engine family and to not certify emissions over powertrain cycles under ~~§40-CFR 10367.5450~~, we will not presume you are responsible for emissions over the powertrain cycles. However, where we determine that you are responsible in whole or in part for the emission exceedance in such cases, we may require that you participate in any recall of the affected vehicles. Note that this provision to limit your responsibility does not apply if you also hold the certificate of conformity for the vehicle.

\* \* \* \* \*

**Subpart H—Averaging, Banking, and Trading for Certification**

34. Amend § 1036.705 by revising paragraph (c) introductory text, redesignating paragraph (c)(4) as paragraph (c)(5), and adding a new paragraph (c)(4) to read as follows:

**§ 1036.705 Generating and calculating emission credits.**

\* \* \* \* \*

(c) ~~Compliance with the requirements of this subpart is determined at the end of the model year by calculating emission credits based on actual production volumes, excluding the following engines: As described in § 1036.730, compliance with the requirements of this subpart is determined at the end of the model year based on actual U.S.-directed production volumes. Keep appropriate records to document these production volumes. Do not include any of the following engines to calculate emission credits:~~

\* \* \* \* \*

(4) Engines certified to state emission standards that are different than the emission standards in this part.

(5) Any other engines if we indicate elsewhere in this part that they are not to be included in the calculations of this subpart.

\* \* \* \* \*

35. Amend § 1036.725 by revising paragraph (b)(2) to read as follows:

**§ 1036.725 Required information for certification.**

\* \* \* \* \*

(b) \* \* \*

(2) ~~Detailed eC~~Calculations of projected emission credits (positive or negative) based on projected ~~U.S.-directed~~ production volumes as described in § 1036.705(c). We may require you to include similar calculations from your other engine families to project your net credit balances for the model year. If you project negative emission credits for a family, state the source of positive emission credits you expect to use to offset the negative emission credits.

36. Amend § 1036.730 by revising paragraphs (b)(4) and (f)(1) to read as follows:

**§ 1036.730 ABT reports.**

\* \* \* \* \*

(b) \* \* \*

(4) The projected and actual ~~U.S.-directed~~ production volumes for calculating emission credits for the model year. If you changed an FEL/FCL during the model year, identify the actual ~~U.S.-directed~~ production volume associated with each FEL/FCL.

\* \* \* \* \*

(f) \* \* \*

(1) If you notify us by the deadline for submitting the final report or we determine by September 30 after the end of the model year that errors mistakenly decreased your balance of emission credits, you may correct the errors and recalculate the balance of emission credits. If you notify us that errors mistakenly decreased your balance of emission credits after the deadline for submitting the final report, you may correct the errors and recalculate the balance of emission credits after applying a 10 percent discount to the credit correction, but only if you notify us within 24 months after the deadline for submitting the final report. You may not make these corrections for errors that are determined later than September 30 after the end of the model year. ~~If you report a negative balance of emission credits, we may disallow corrections under this paragraph (f)(1).~~

\* \* \* \* \*

37. Amend § 1036.735 by revising paragraph (d) to read as follows:

**§ 1036.735 Recordkeeping.**

\* \* \* \* \*

(d) Keep appropriate records to document production volumes of engines that generate or use emission credits under the ABT program. For example, keep available ~~Keep~~ records of the engine identification number (usually the serial number) for each engine you produce that generates or uses emission credits ~~under the ABT program~~. You may identify these numbers as a range. If you change the FEL/FCL after the start of production, identify the date you started using each FEL/FCL and the range of engine identification numbers associated with each FEL/FCL. You must also identify the purchaser and destination for each engine you produce to the extent this information is available.

\* \* \* \* \*

**Subpart I—Definitions and Other Reference Information**

38. Amend § 1036.801 by:

- a. Adding a definition of “Carbon-containing fuel” in alphabetical order.
- b. Removing the definitions of “Criteria pollutants” and “Greenhouse gas”.
- c. Revising the definition of “Hybrid”.
- d. Removing the definitions of “Hybrid engine” and “Hybrid powertrain”.
- e. Revising the definition of “Mild hybrid”.
- f. Adding a definition of “Neat” in alphabetical order.
- g. Revising the definitions of “Small manufacturer” and “U.S.-directed production volume”.

The additions and revisions read as follows:

**§ 1036.801 Definitions.**

\* \* \* \* \*

Carbon-containing fuel has the meaning given in 40 CFR 1065.1001.

\* \* \* \* \*

Criteria pollutants means emissions of NO<sub>x</sub>, HC, PM, and CO.

Greenhouse gas means one or more compounds regulated under this part based primarily on their impact on the climate. This generally includes CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O.

Hybrid means relating to an engine or powertrain that includes a Rechargeable Energy Storage System. Hybrid engines store and recover energy in a way that is integral to the engine or otherwise upstream of the vehicle's transmission. Examples of hybrid engines include engines with hybrid components connected to the front end of the engine (P0), at the crankshaft before the clutch (P1), or connected between the clutch and the transmission where the clutch upstream of the hybrid feature is in addition to the transmission clutch(s) (P2). Engine-based systems that recover kinetic energy to power an electric heater in the aftertreatment are themselves not sufficient to qualify as a hybrid engine. Provisions that apply for hybrid powertrains apply equally for hybrid engines, except as specified. Note that certain provisions in this part treat hybrid powertrains intended for vehicles that include regenerative braking different than those intended for vehicles that do not include regenerative braking. The definition of hybrid includes plug-in hybrid electric powertrains, an engine or powertrain that includes energy storage features other than a conventional battery system or conventional flywheel. Supplemental electrical batteries and hydraulic accumulators are examples of hybrid energy storage systems. Note that certain provisions in this part treat hybrid engines and hybrid powertrains intended for vehicles that include regenerative braking different than those intended for vehicles that do not include regenerative braking.

Hybrid engine means a hybrid system with features for storing and recovering energy that are integral to the engine or are otherwise upstream of the vehicle's transmission other than a conventional battery system or conventional flywheel. Supplemental electrical batteries and hydraulic accumulators are examples of hybrid energy storage systems. Examples of hybrids that could be considered hybrid engines are P0, P1, and P2 hybrids where hybrid features are connected to the front end of the engine, at the crankshaft, or connected between the clutch and the transmission where the clutch upstream of the hybrid feature is in addition to the transmission clutch(s), respectively. Note other examples of systems that qualify as hybrid engines are systems that recover kinetic energy and use it to power an electric heater in the aftertreatment.

Hybrid powertrain means a powertrain that includes energy storage features other than a conventional battery system or conventional flywheel. Supplemental electrical batteries and hydraulic accumulators are examples of hybrid energy storage systems. Note other examples of systems that qualify as hybrid powertrains are systems that recover kinetic energy and use it to power an electric heater in the aftertreatment.



\* \* \* \* \*

*Mild hybrid* means relating to a hybrid engine or hybrid powertrain with regenerative braking capability where the system recovers less than 20 percent of the total braking energy over the transient cycle defined in appendix A of 40 CFR part 1037.

\* \* \* \* \*

Neat has the meaning given in § 1065.1001.

\* \* \* \* \*

*Small manufacturer* means a manufacturer meeting the criteria specified in 13 CFR 121.201. The employee and revenue limits apply to the total number of employees and total revenue together for all affiliated companies (as defined in 40 CFR 1068.30). Note that manufacturers with low production volumes may or may not be “small manufacturers”.

\* \* \* \* \*

*U.S.-directed production volume* means the number of engines, subject to the requirements of this part, produced by a manufacturer for which the manufacturer has a reasonable assurance that sale was or will be made to ultimate purchasers in the United States. ~~This does not include~~ Note that this includes engines certified to state emission standards that are different than the emission standards in this part.

\* \* \* \* \*

39. Amend § 1036.805 by adding an entry to Table 5 in alphabetical order to read as follows:

**§ 1036.805 Symbols, abbreviations, and acronyms.**

\* \* \* \* \*

(e) \* \* \*

TABLE 5 TO PARAGRAPH (e) OF § 1036.805—OTHER ACRONYMS AND ABBREVIATIONS

<b>Acronym</b>	<b>Meaning</b>
* * * * *	
<u>GCWR</u>	<u>gross combined weight rating.</u>
* * * * *	

\* \* \* \* \*

40. Amend § 1036.810 by adding paragraph (e) to read as follows:

**§ 1036.810 Incorporation by reference.**

\* \* \* \* \*

(e) U.S. EPA, Office of Air and Radiation, 2565 Plymouth Road, Ann Arbor, MI 48105; [www.epa.gov](http://www.epa.gov).

(1) Greenhouse gas Emissions Model (GEM) Phase 2, Version 4.0, April 2022 (“GEM Phase 2, Version 4.0”); IBR approved for § 1036.545(a).

(2) [Reserved]

41. Amend § 1036.815 by revising paragraph (b) to read as follows:

**§ 1036.815 Confidential information.**

\* \* \* \* \*

(b) Emission data or information that is publicly available cannot be treated as confidential business information as described in 40 CFR 1068.11. Data that vehicle manufacturers need for demonstrating compliance with greenhouse gas emission standards, including fuel-consumption data as described in §§ 1036.535 and ~~40-CFR-10367.5450~~, also qualify as emission data for purposes of confidentiality determinations.

**PART 1037— CONTROL OF EMISSIONS FROM NEW HEAVY-DUTY MOTOR VEHICLES**

42. The authority citation for part 1037 continues to read as follows:  
Authority: 42 U.S.C. 7401 - 7671q.

**Subpart A—Overview and Applicability**

43. Amend § 1037.1 by revising paragraph (a) to read as follows:

**§ 1037.1 Applicability.**

(a) The regulations in this part 1037 apply for all new heavy-duty vehicles, except as provided in §§ 1037.5 ~~and 1037.104~~. This includes battery electric vehicles, fuel cell electric vehicles, and vehicles fueled by conventional and alternative fuels. ~~This also includes certain trailers as described in §§ 1037.5, 1037.150, and 1037.801.~~

\* \* \* \* \*

44. Amend § 1037.5 by:

- a. Revising paragraph (e).
- b. Removing paragraphs (g) and (h).
- c. Redesignating paragraph (i) as paragraph (g).

The revisions read as follows:

**§ 1037.5 Excluded vehicles.**

\* \* \* \* \*

(e) Vehicles subject to the heavy-duty emission standards of 40 CFR part 86. See 40 CFR ~~86.1816 and 86.1819~~ for part 86, subpart S, for emission standards that apply for these vehicles. ~~This exclusion generally applies for complete heavy-duty vehicles at or below 14,000 pounds GVWR.~~

\* \* \* \* \*

**Subpart B—Emission Standards and Related Requirements**

45. Amend § 1037.101 by revising paragraphs (a)(2) and (b)(2) and (3) to read as follows:

**§ 1037.101 Overview of emission standards.**

\* \* \* \* \*

(a) \* \* \*

(2) *Exhaust emissions of greenhouse gases.* ~~These pollutants are described collectively in this part as “greenhouse gas pollutants” because they are regulated primarily based on their impact on the climate.~~ Emission standards apply as follows for greenhouse gas (GHG) emissions:

(i) CO<sub>2</sub>, ~~CH<sub>4</sub>, and N<sub>2</sub>O~~ emission standards apply as described in §§ 1037.105 ~~through 1037.107 and 1037.106.~~ No CH<sub>4</sub> or N<sub>2</sub>O standards apply under this part. See 40 CFR part 1036 for CH<sub>4</sub> or N<sub>2</sub>O standards that apply to engines used in these vehicles.

(ii) Hydrofluorocarbon standards apply as described in § 1037.115(e). These pollutants are also “greenhouse gas pollutants” but are treated separately from exhaust greenhouse gas pollutants listed in paragraph (a)(2)(i) of this section.

\* \* \* \* \*

(b) \* \* \*

(2) For greenhouse gas pollutants, vehicles are regulated in the following groups:

(i) Tractors above 26,000 pounds GVWR.

(ii) ~~Trailers.~~

~~(iii)~~ Vocational vehicles.

(3) The greenhouse gas emission standards apply differently depending on the vehicle service class as described in § 1037.140. In addition, standards apply differently for vehicles with spark-ignition and compression-ignition engines. References in this part 1037 to “spark-ignition” or “compression-ignition” generally relate to the application of standards under 40 CFR 1036.140. For example, a vehicle with an engine certified to spark-ignition standards under 40 CFR part 1036 is generally subject to requirements under this part 1037 that apply for spark-ignition vehicles. However, note that emission standards for Heavy HDE are considered to be compression-ignition standards for purposes of applying vehicle emission standards under this part. Also, for spark-ignition engines voluntarily certified as compression-ignition engines under 40 CFR part 1036, you must choose at certification whether your vehicles are subject to spark-ignition standards or compression-ignition standards. Heavy-duty vehicles with no installed propulsion engine, such as battery electric vehicles, are subject to compression-ignition emission standards for the purpose of calculating emission credits.

\* \* \* \* \*

46. Amend § 1037.102 by revising paragraph (b) introductory text to read as follows:

**§ 1037.102 Criteria eExhaust emission standards ~~—~~for NO<sub>x</sub>, HC, PM, and CO.**

\* \* \* \* \*

(b) Heavy-duty vehicles with no installed propulsion engine, such as battery electric vehicles, are subject to criteria pollutant standards under this part. The emission standards that apply are the same as the standards that apply for compression-ignition engines under 40 CFR 86.007-11 and 1036.104 for a given model year.

\* \* \* \* \*

47. Amend § 1037.105 by:
- a. Revising paragraphs (a)(1) and (2) and (b)(1) and (4)
  - b. Removing and reserving paragraph (c).
  - c. Revising paragraph (h)(1).

The revisions read as follows:

**§ 1037.105 CO<sub>2</sub> emission standards for vocational vehicles.**

(a) \* \* \*

(1) Heavy-duty vehicles at or below 14,000 pounds GVWR that are not subject to excluded from the standards in 40 CFR 86.1819 greenhouse gas standards in 40 CFR part 86, subpart S. or that use engines certified under § 1037.150(m).

(2) Vehicles above 14,000 pounds GVWR and at or below 26,000 pounds GVWR, but not certified to the vehicle standards in 40 CFR 86.1819 greenhouse gas standards in 40 CFR part 86, subpart S.

\* \* \* \* \*

(b) \* \* \*

(1) Model year 2027 and later vehicles are subject to CO<sub>2</sub> standards corresponding to the selected subcategories as shown in the following table:

TABLE 1 OF PARAGRAPH (b)(1) OF § 1037.105—PHASE 3 CO<sub>2</sub> STANDARDS FOR MODEL YEAR 2027 AND LATER VOCATIONAL VEHICLES (g/ton-mile)

<u>Model Year</u>	<u>Subcategory</u>	<u>Compression-ignition Engine</u>			<u>Spark-ignition Engine</u>	
		<u>Light HDV</u>	<u>Medium HDV</u>	<u>Heavy HDV</u>	<u>Light HDV</u>	<u>Medium HDV</u>
<u>2027</u>	<u>Urban</u>	<u>294</u>	<u>213</u>	<u>232</u>	<u>340</u>	<u>252</u>
	<u>Multi-Purpose</u>	<u>257</u>	<u>190</u>	<u>193</u>	<u>299</u>	<u>223</u>
	<u>Regional</u>	<u>218</u>	<u>173</u>	<u>152</u>	<u>246</u>	<u>202</u>
<u>2028</u>	<u>Urban</u>	<u>275</u>	<u>209</u>	<u>228</u>	<u>321</u>	<u>248</u>
	<u>Multi-Purpose</u>	<u>238</u>	<u>186</u>	<u>189</u>	<u>280</u>	<u>219</u>
	<u>Regional</u>	<u>199</u>	<u>169</u>	<u>148</u>	<u>227</u>	<u>198</u>
<u>2029</u>	<u>Urban</u>	<u>255</u>	<u>202</u>	<u>225</u>	<u>301</u>	<u>241</u>
	<u>Multi-Purpose</u>	<u>218</u>	<u>179</u>	<u>186</u>	<u>260</u>	<u>212</u>
	<u>Regional</u>	<u>179</u>	<u>162</u>	<u>145</u>	<u>207</u>	<u>191</u>
<u>2030</u>	<u>Urban</u>	<u>238</u>	<u>195</u>	<u>200</u>	<u>284</u>	<u>234</u>
	<u>Multi-Purpose</u>	<u>201</u>	<u>172</u>	<u>161</u>	<u>243</u>	<u>205</u>
	<u>Regional</u>	<u>162</u>	<u>155</u>	<u>120</u>	<u>190</u>	<u>184</u>
<u>2031</u>	<u>Urban</u>	<u>219</u>	<u>188</u>	<u>193</u>	<u>265</u>	<u>227</u>
	<u>Multi-Purpose</u>	<u>182</u>	<u>165</u>	<u>154</u>	<u>224</u>	<u>198</u>
	<u>Regional</u>	<u>143</u>	<u>148</u>	<u>113</u>	<u>171</u>	<u>177</u>
<u>2032 and later</u>	<u>Urban</u>	<u>179</u>	<u>176</u>	<u>177</u>	<u>225</u>	<u>215</u>
	<u>Multi-Purpose</u>	<u>142</u>	<u>153</u>	<u>138</u>	<u>184</u>	<u>186</u>
	<u>Regional</u>	<u>103</u>	<u>136</u>	<u>97</u>	<u>131</u>	<u>165</u>

TABLE 1 OF § 1037.105—PHASE 2 CO<sub>2</sub> STANDARDS FOR MODEL YEAR 2027 AND LATER VOCATIONAL VEHICLES (g/ton-mile)

<u>Engine cycle</u>	<u>Vehicle size</u>	<u>Multi-purpose</u>	<u>Regional</u>	<u>Urban</u>
<u>Compression-ignition</u>	<u>Light HDV</u>	<u>330</u>	<u>291</u>	<u>367</u>
<u>Compression-ignition</u>	<u>Medium HDV</u>	<u>235</u>	<u>218</u>	<u>258</u>
<u>Compression-ignition</u>	<u>Heavy HDV</u>	<u>230</u>	<u>189</u>	<u>269</u>
<u>Spark-ignition</u>	<u>Light HDV</u>	<u>372</u>	<u>319</u>	<u>413</u>

<del>Spark ignition</del>	<del>Medium HDV</del>	<del>268</del>	<del>247</del>	<del>297</del>
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\* \* \* \* \*

(4) Model year 2014 through 2020 vehicles are subject to Phase 1 CO<sub>2</sub> standards as shown in the following table:

TABLE 4 OF PARAGRAPH (b)(4) § 1037.105—PHASE 1 CO<sub>2</sub> STANDARDS FOR MODEL YEAR 2014 THROUGH 2020 VOCATIONAL VEHICLES (g/ton-mile)

Vehicle size	CO <sub>2</sub> standard for model years 2014-2016	CO <sub>2</sub> standard for model year 2017- <del>and later-2020</del>
Light HDV	388	373
Medium HDV	234	225
Heavy HDV	226	222

(c) ~~No CH<sub>4</sub> or N<sub>2</sub>O standards apply under this section. See 40 CFR part 1036 for CH<sub>4</sub> or N<sub>2</sub>O standards that apply to engines used in these vehicles.~~ [Reserved]

\* \* \* \* \*

(h) \* \* \*

(1) The following alternative emission standards apply by vehicle type and model year as follows:

TABLE 5 OF PARAGRAPH (h)(1) OF § 1037.105—OPTIONAL PHASE 3 CO<sub>2</sub> STANDARDS FOR MODEL YEAR 2027 AND LATER CUSTOM CHASSIS VOCATIONAL VEHICLES (g/ton-mile)

<u>Optional Custom Chassis Vehicle Type</u>	<u>Model Year 2027</u>	<u>Model Year 2028</u>	<u>Model Year 2029</u>	<u>Model Year 2030</u>	<u>Model Year 2031</u>	<u>Model Year 2032 and later</u>
<u>School Bus</u>	<u>190</u>	<u>182</u>	<u>176</u>	<u>168</u>	<u>163</u>	<u>149</u>
<u>Other Bus</u>	<u>286</u>	<u>269</u>	<u>255</u>	<u>237</u>	<u>220</u>	<u>189</u>
<u>Coach Bus</u>	<u>205</u>	<u>205</u>	<u>205</u>	<u>185</u>	<u>164</u>	<u>154</u>
<u>Refuse Hauler</u>	<u>253</u>	<u>241</u>	<u>232</u>	<u>221</u>	<u>212</u>	<u>191</u>
<u>Concrete Mixer</u>	<u>259</u>	<u>250</u>	<u>240</u>	<u>231</u>	<u>224</u>	<u>205</u>
<u>Motor home</u>	<u>226</u>	<u>226</u>	<u>226</u>	<u>226</u>	<u>226</u>	<u>226</u>
<u>Mixed-use vehicle</u>	<u>316</u>	<u>316</u>	<u>316</u>	<u>316</u>	<u>316</u>	<u>316</u>
<u>Emergency vehicle</u>	<u>319</u>	<u>319</u>	<u>319</u>	<u>319</u>	<u>319</u>	<u>319</u>

TABLE ~~65~~ OF PARAGRAPH (h)(1) OF § 1037.105—PHASE 2 CUSTOM CHASSIS STANDARDS FOR MODEL YEARS 2021 THROUGH 2026 (g/ton-mile)

Vehicle type <sup>a</sup>	Assigned vehicle service class	Model Year 2021-2026
School bus	Medium HDV	291
Motor home	Medium HDV	228
Coach bus	Heavy HDV	210
Other bus	Heavy HDV	300
Refuse hauler	Heavy HDV	313
Concrete mixer	Heavy HDV	319
Mixed-use vehicle	Heavy HDV	319
Emergency vehicle	Heavy HDV	324

\* \* \* \* \*

48. Amend § 1037.106 by revising paragraph (b), removing and reserving paragraph (c), and revising paragraphs (f)(2) introductory text and (f)(2)(i) to read as follows:

**§ 1037.106 ~~CO<sub>2</sub> Exhaust~~ emission standards for tractors above 26,000 pounds GVWR.**

\* \* \* \* \*

(b) ~~The~~ CO<sub>2</sub> standards in this paragraph (b) for tractors above 26,000 pounds GVWR in Table 1 of this section apply based on modeling and testing as described in subpart F of this part. The provisions of § 1037.241 specify how to comply with these standards ~~in this paragraph (b)~~.

(1) Model year 2027 and later tractors are subject to CO<sub>2</sub> standards corresponding to the selected subcategories as shown in the following tables:

TABLE 1 OF PARAGRAPH (b)(1) OF § 1037.106—CO<sub>2</sub> EMISSION STANDARDS FOR MODEL YEAR 2027 AND LATER TRACTORS (g/TON-MILE)

<u>Model Year</u>	<u>Roof Height</u>	<u>Class 7 All Cab Styles</u>	<u>Class 8 Day Cab</u>	<u>Class 8 Sleeper Cab</u>	<u>Heavy-Haul</u>
<u>2027</u>	<u>Low</u>	<u>86.6</u>	<u>66.1</u>	<u>64.1</u>	<u>48.3</u>
	<u>Mid</u>	<u>93.1</u>	<u>70.2</u>	<u>69.6</u>	
	<u>High</u>	<u>90.0</u>	<u>68.1</u>	<u>64.3</u>	
<u>2028</u>	<u>Low</u>	<u>84.7</u>	<u>64.6</u>	<u>64.1</u>	<u>48.3</u>
	<u>Mid</u>	<u>91.0</u>	<u>68.6</u>	<u>69.6</u>	
	<u>High</u>	<u>88.0</u>	<u>66.6</u>	<u>64.3</u>	
<u>2029</u>	<u>Low</u>	<u>81.8</u>	<u>62.4</u>	<u>64.1</u>	<u>48.3</u>
	<u>Mid</u>	<u>87.9</u>	<u>66.3</u>	<u>69.6</u>	
	<u>High</u>	<u>85.0</u>	<u>64.3</u>	<u>64.3</u>	
<u>2030</u>	<u>Low</u>	<u>77.0</u>	<u>58.7</u>	<u>57.7</u>	<u>43.0</u>
	<u>Mid</u>	<u>82.7</u>	<u>62.4</u>	<u>62.6</u>	
	<u>High</u>	<u>80.0</u>	<u>60.6</u>	<u>57.9</u>	
<u>2031</u>	<u>Low</u>	<u>67.3</u>	<u>51.4</u>	<u>51.3</u>	<u>42.5</u>
	<u>Mid</u>	<u>72.4</u>	<u>54.6</u>	<u>55.7</u>	
	<u>High</u>	<u>70.0</u>	<u>53.0</u>	<u>51.4</u>	
<u>2032 and later</u>	<u>Low</u>	<u>63.5</u>	<u>48.4</u>	<u>48.1</u>	<u>41.1</u>
	<u>Mid</u>	<u>68.2</u>	<u>51.5</u>	<u>52.2</u>	
	<u>High</u>	<u>66.0</u>	<u>50.0</u>	<u>48.2</u>	

(2) Model year 2026 and earlier tractors are subject to CO<sub>2</sub> standards corresponding to the selected subcategory as shown in the following table:

TABLE 24 OF PARAGRAPH (b)(2) OF § 1037.106—CO<sub>2</sub> STANDARDS FOR MODEL YEAR 2026 AND EARLIER CLASS 7 AND CLASS 8 TRACTORS BY MODEL YEAR (g/ton-mile)

<u>Subcategory<sup>a</sup></u>	<u>Phase 1 standards for model years 2014-2016</u>	<u>Phase 1 standards for model years 2017-2020</u>	<u>Phase 2 standards for model years 2021-2023</u>	<u>Phase 2 standards for model years 2024-2026</u>
<u>Class 7 Low-Roof (all cab styles)</u>	<u>107</u>	<u>104</u>	<u>105.5</u>	<u>99.8</u>
<u>Class 7 Mid-Roof (all cab styles)</u>	<u>119</u>	<u>115</u>	<u>113.2</u>	<u>107.1</u>
<u>Class 7 High-Roof (all cab styles)</u>	<u>124</u>	<u>120</u>	<u>113.5</u>	<u>106.6</u>
<u>Class 8 Low-Roof Day Cab</u>	<u>81</u>	<u>80</u>	<u>80.5</u>	<u>76.2</u>

Class 8 Low-Roof Sleeper Cab	68	66	72.3	68.0
Class 8 Mid-Roof Day Cab	88	86	85.4	80.9
Class 8 Mid-Roof Sleeper Cab	76	73	78.0	73.5
Class 8 High-Roof Day Cab	92	89	85.6	80.4
Class 8 High-Roof Sleeper Cab	75	72	75.7	70.7
Heavy-Haul Tractors	—	—	52.4	50.2

~~(c) No CH<sub>4</sub> or N<sub>2</sub>O standards apply under this section. See 40 CFR part 1036 for CH<sub>4</sub> or N<sub>2</sub>O standards that apply to engines used in these vehicles. [Reserved]~~

~~\* \* \* \* \*~~

~~(f) \* \* \*~~

~~(2) You may optionally certify Class 7 tractors not covered by paragraph (f)(1) of this section to the standards and useful life for Class 8 tractors. This paragraph (f)(2) applies equally for hybrid vehicles, battery electric vehicles, and fuel cell electric vehicles. Credit provisions apply as follows:~~

~~(i) If you certify all your Class 7 tractors to Class 8 standards, you may use these Heavy HDV credits without restriction. This paragraph (f)(2)(i) applies equally for hybrid and electric vehicles.~~

~~\* \* \* \* \*~~

**§ 1037.107—[Removed]**

49. Remove § 1037.107.

**~~§ 1037.107—Emission standards for trailers.~~**

~~The exhaust emission standards specified in this section apply to trailers based on the effect of trailer designs on the performance of the trailer in conjunction with a tractor; this accounts for the effect of the trailer on the tractor's exhaust emissions, even though trailers themselves have no exhaust emissions.~~

~~(a) Standards apply for trailers based on modeling and testing as described in subpart F of this part, as follows:~~

~~(1) Different levels of stringency apply for box vans depending on features that may affect aerodynamic performance. You may optionally meet less stringent standards for different trailer types, which we characterize as follows:~~

~~(i) For trailers 35 feet or longer, you may designate as “non-aero box vans” those box vans that have a rear lift gate or rear hinged ramp, and at least one of the following side features: side lift gate, side-mounted pull-out platform, steps for side-door access, a drop-deck design, or belly boxes that occupy at least half the length of both sides of the trailer between the centerline of the landing gear and the leading edge of the front wheels. For trailers less than 35 feet long, you may designate as “non-aero box vans” any refrigerated box vans with at least one of the side features identified for longer trailers.~~

~~(ii) You may designate as “partial-aero box vans” those box vans that have at least one of the side features identified in paragraph (a)(1)(i) of this section. Long box vans may also qualify as partial-aero box vans if they have a rear lift gate or rear hinged ramp. Note that this paragraph (a)(1)(ii) does not apply for box vans designated as “non-aero box vans” under paragraph (a)(1)(i) of this section.~~

~~(iii) “Full-aero box vans” are box vans that are not designated as non-aero box vans or partial-aero box vans under this paragraph (a)(1).~~

~~(2) CO<sub>2</sub> standards apply for full-aero box vans as specified in the following table:~~

~~TABLE 1 OF § 1037.107—PHASE 2 CO<sub>2</sub> STANDARDS FOR FULL AERO BOX VANS (g/ton-mile)~~

Model year	Dry van		Refrigerated van	
	Short	Long	Short	Long
2018-2020	125.4	81.3	129.1	83.0
2021-2023	123.7	78.9	127.5	80.6
2024-2026	120.9	77.2	124.7	78.9
2027+	118.8	75.7	122.7	77.4

~~(3) CO<sub>2</sub> standards apply for partial aero box vans as specified in the following table:~~

~~TABLE 2 OF § 1037.107—PHASE 2 CO<sub>2</sub> STANDARDS FOR PARTIAL AERO BOX VANS (g/ton-mile)~~

Model year	Dry van		Refrigerated van	
	Short	Long	Short	Long
2018-2020	125.4	81.3	129.1	83.0
2021+	123.7	80.6	127.5	82.3

~~(4) Non-box trailers and non-aero box vans must meet standards as follows:~~

~~(i) Trailers must use automatic tire inflation systems or tire pressure monitoring systems with wheels on all axles.~~

~~(ii) Non-box trailers must use tires with a TRRL at or below 5.1 kg/tonne. Through model year 2020, non-box trailers may instead use tires with a TRRL at or below 6.0 kg/tonne.~~

~~(iii) Non-aero box vans must use tires with a TRRL at or below 4.7 kg/tonne. Through model year 2020, non-aero box vans may instead use tires with a TRRL at or below 5.1 kg/tonne.~~

~~(5) Starting in model year 2027, you may generate or use emission credits for averaging to demonstrate compliance with the standards specified in paragraph (a)(2) of this section as described in subpart H of this part. This requires that you specify a Family Emission Limit (FEL) for CO<sub>2</sub> for each vehicle subfamily. The FEL may not be less than the result of the emission calculation in § 1037.515. The FEL may not be greater than the appropriate standard for model year 2018 trailers. These FELs serve as the emission standards for the specific vehicle subfamily instead of the standards specified in paragraph (a) of this section. You may not use averaging for non-box trailers, partial-aero box vans, or non-aero box vans that meet standards under paragraph (a)(3) or (a)(4) of this section, and you may not use emission credits for banking or trading for any trailers.~~

~~(6) The provisions of § 1037.241 specify how to comply with the standards of this section.~~

~~(b) No CH<sub>4</sub>, N<sub>2</sub>O, or HFC standards apply under this section.~~

~~(c) The emission standards of this section apply for a useful life of 10 years.~~

50. Amend § 1037.115 by revising paragraphs (a) and (e)(1) and adding paragraph (f) to read as follows:

**§ 1037.115 Other requirements.**

\* \* \* \* \*

(a) *Adjustable parameters.* Vehicles that have adjustable parameters must meet all the requirements of this part for any adjustment in the practically adjustable range. We may require that you set adjustable parameters to any specification within the practically adjustable range



during any testing. See 40 CFR 1068.50 for general provisions related to adjustable parameters. You must ensure safe vehicle operation throughout the practically adjustable range of each adjustable parameter, including consideration of production tolerances. Note that adjustable roof fairings ~~and trailer rear fairings~~ are deemed not to be adjustable parameters.

\* \* \* \* \*

(e) \* \* \*

(1) This paragraph (e) is intended to address air conditioning systems for which the primary purpose is to cool the driver compartment. This would generally include all cab-complete pickups and vans. ~~This paragraph (e) does not apply for refrigeration units on trailers.~~ Similarly, it does not apply for self-contained air conditioning used to cool passengers or refrigeration units used to cool cargo on vocational vehicles. ~~Air conditioning and refrigeration units may be considered self-contained whether or not they draw electrical power from engines used to propel the vehicles.~~ For purposes of this paragraph (e), a self-contained system is an enclosed unit with its own evaporator and condenser even if it draws power from the engine.

\* \* \* \* \*

(f) Battery durability monitor. Battery electric vehicles and plug-in hybrid electric vehicles must meet monitoring requirements related to batteries serving as a Rechargeable Energy Storage System from GTR No. 22 (incorporated by reference in § 1037.810). The requirements of this section apply starting in model year 2030. The following clarifications and adjustments to GTR No. 22 apply for vehicles subject to this section:

(1) Install a customer-accessible display that monitors, estimates, and communicates the vehicle's State of Certified Energy (SOCE) include information in the application for certification as described in §1037.205. Monitoring requirements related to State of Certified Range (SOCR) do not apply.

(3) Accuracy requirements for SOCE in GTR No. 22 do not apply. Minimum Performance Requirements for battery durability also do not apply.

(4) For battery electric vehicles, use good engineering judgment to develop a test procedure for determining useable battery energy (UBE).

(5) For plug-hybrid electric vehicles, determine UBE as described in 40 CFR 1036.545.

51. Amend § 1037.120 by:

- a. Revising paragraph (b)(1)(iii).
- b. Removing paragraph (b)(1)(iv).
- c. Revising paragraph (c).

The revisions read as follows:

**§ 1037.120 Emission-related warranty requirements.**

\* \* \* \* \*

(b) \* \* \*

(1) \* \* \*

(iii) ~~5 years for trailers (except tires).~~

~~(iv) 1 year for tires installed on trailers, and~~ 2 years or 24,000 miles for ~~all other~~ tires.

\* \* \* \* \*

(c) *Components covered.* The emission-related warranty covers tires, automatic tire inflation systems, tire pressure monitoring systems, vehicle speed limiters, idle-reduction systems, ~~hybrid system components, and~~ devices added to the vehicle to improve aerodynamic performance (not including standard components such as hoods or mirrors even if they have been optimized for

aerodynamics), fuel cell stacks, and RESS and other components used with hybrid systems, battery electric vehicles, and fuel cell electric vehicles to the extent such emission-related components are included in your application for certification. The emission-related warranty also covers other added emission-related components to the extent they are included in your application for certification, and any other components whose failure would increase a vehicle's CO<sub>2</sub> emissions. The emission-related warranty covers all components whose failure would increase a vehicle's emissions of air conditioning refrigerants (for vehicles subject to air conditioning leakage standards), and it covers all components whose failure would increase a vehicle's evaporative and refueling emissions (for vehicles subject to evaporative and refueling emission standards). The emission-related warranty covers components that are part of your certified configuration even if another company produces the component. ~~Your emission-related warranty does not need to cover components whose failure would not increase a vehicle's emissions of any regulated pollutant.~~

\* \* \* \* \*

52. Amend § 1037.130 by revising paragraph (a) to read as follows:

**§ 1037.130 Assembly instructions for secondary vehicle manufacturers.**

(a) If you sell a certified incomplete vehicle to a secondary vehicle manufacturer, give the secondary vehicle manufacturer instructions for completing vehicle assembly consistent with the requirements of this part. Include all information necessary to ensure that the final vehicle assembly (including the engine ~~for vehicles other than trailers~~) will be in its certified configuration.

\* \* \* \* \*

53. Amend § 1037.140 by revising paragraph (g)(5) introductory text to read as follows:

**§ 1037.140 Classifying vehicles and determining vehicle parameters.**

\* \* \* \* \*

(g) \* \* \*

(5) Heavy-duty vehicles with no installed propulsion engine, such as battery electric vehicles, are divided as follows:

\* \* \* \* \*

54. Amend § 1037.150 by:

- a. Revising paragraphs (c), (f) and (p).
- b. Removing paragraphs (u) through (x).
- c. Redesignating paragraphs (y) through (bb) as paragraphs (u) through (x).
- d. Revising the redesignated paragraph (x).
- e. Adding a new paragraph (y).

The revisions and addition read as follows:

**§ 1037.150 Interim provisions.**

\* \* \* \* \*

(c) *Small manufacturers.* The following provisions apply for small manufacturers:

- (1) The following provisions apply through model year 2026:
  - (i) ~~Small manufacturers are not subject to the greenhouse gas standards of § 1037.107 for trailers with a date of manufacture before January 1, 2019.~~

~~(2)~~ The greenhouse gas standards of §§ 1037.105 and 1037.106 are optional for small manufacturers producing vehicles with a date of manufacture before January 1, 2022. In addition, small manufacturers producing vehicles that run on any fuel other than gasoline, E85, or diesel fuel may delay complying with every later standard under this part by one model year.

~~(ii)~~<sup>3</sup> Qualifying manufacturers must notify the Designated Compliance Officer each model year before introducing excluded vehicles into U.S. commerce. This notification must include a description of the manufacturer’s qualification as a small business under 13 CFR 121.201. Manufacturers must label excluded vehicles with the following statement: “THIS VEHICLE IS EXCLUDED UNDER 40 CFR 1037.150(c).”

~~(iii)~~<sup>4</sup> Small manufacturers may meet Phase 1 standards instead of Phase 2 standards in the first year Phase 2 standards apply to them if they voluntarily comply with the Phase 1 standards for the full preceding year. Specifically, small manufacturers may certify their model year 2022 vehicles to the Phase 1 greenhouse gas standards of §§ 1037.105 and 1037.106 if they certify all the vehicles from their annual ~~U.S.-directed~~ production volume included in emission credit calculations for~~to~~ the Phase 1 standards starting on or before January 1, 2021.

(2) The following provisions apply for model year 2027 and later for qualifying small manufacturers:

(i) The following standards apply for vocational vehicles instead of the standards specified in § 1037.105:

TABLE 1 OF PARAGRAPH (C)(2)(i) OF § 1037.150—SMALL MANUFACTURER CO<sub>2</sub> STANDARDS VOCATIONAL VEHICLES (g/ton-mile)

<u>Engine cycle</u>	<u>Vehicle size</u>	<u>Multi-purpose</u>	<u>Regional</u>	<u>Urban</u>
<u>Compression-ignition</u>	<u>Light HDV</u>	<u>330</u>	<u>291</u>	<u>367</u>
<u>Compression-ignition</u>	<u>Medium HDV</u>	<u>235</u>	<u>218</u>	<u>258</u>
<u>Compression-ignition</u>	<u>Heavy HDV</u>	<u>230</u>	<u>189</u>	<u>269</u>
<u>Spark-ignition</u>	<u>Light HDV</u>	<u>372</u>	<u>319</u>	<u>413</u>
<u>Spark-ignition</u>	<u>Medium HDV</u>	<u>268</u>	<u>247</u>	<u>297</u>

TABLE 2 OF PARAGRAPH (C)(2)(i) OF § 1037.150—SMALL MANUFACTURER CO<sub>2</sub> STANDARDS FOR CUSTOM CHASSIS VOCATIONAL VEHICLES (g/ton-mile)

<u>Vehicle type<sup>a</sup></u>	<u>Assigned vehicle service class</u>	<u>MY 2027 and later</u>
<u>School bus</u>	<u>Medium HDV</u>	<u>271</u>
<u>Motor home</u>	<u>Medium HDV</u>	<u>226</u>
<u>Coach bus</u>	<u>Heavy HDV</u>	<u>205</u>
<u>Other bus</u>	<u>Heavy HDV</u>	<u>286</u>
<u>Refuse hauler</u>	<u>Heavy HDV</u>	<u>298</u>
<u>Concrete mixer</u>	<u>Heavy HDV</u>	<u>316</u>
<u>Mixed-use vehicle</u>	<u>Heavy HDV</u>	<u>316</u>
<u>Emergency vehicle</u>	<u>Heavy HDV</u>	<u>319</u>

<sup>a</sup>Vehicle types are generally defined in § 1037.801. “Other bus” includes any bus that is not a school bus or a coach bus. A “mixed-use vehicle” is one that meets at least one of the criteria specified in § 1037.631(a)(1) or (2).

(ii) The following standards apply for tractors instead of the standards specified in § 1037.106:

TABLE 3 OF PARAGRAPH (C)(2)(ii) OF § 1037.150— SMALL MANUFACTURER CO<sub>2</sub> STANDARDS FOR CLASS 7 AND CLASS 8 TRACTORS BY SUBCATEGORY (g/ton-mile)

<u>Subcategory<sup>a</sup></u>	<u>Phase 2 standards for model year 2027 and later</u>
<u>Class 7 Low-Roof (all cab styles)</u>	<u>96.2</u>
<u>Class 7 Mid-Roof (all cab styles)</u>	<u>103.4</u>
<u>Class 7 High-Roof (all cab styles)</u>	<u>100.0</u>
<u>Class 8 Low-Roof Day Cab</u>	<u>73.4</u>
<u>Class 8 Low-Roof Sleeper Cab</u>	<u>64.1</u>
<u>Class 8 Mid-Roof Day Cab</u>	<u>78.0</u>
<u>Class 8 Mid-Roof Sleeper Cab</u>	<u>69.6</u>
<u>Class 8 High-Roof Day Cab</u>	<u>75.7</u>
<u>Class 8 High-Roof Sleeper Cab</u>	<u>64.3</u>
<u>Heavy-Haul Tractors</u>	<u>48.3</u>

<sup>a</sup>Subcategory terms are defined in § 1037.801.

(iii) Small manufacturers producing vehicles that run on any fuel other than gasoline, E85, or diesel fuel may delay complying with the model year 2027 standards under this paragraph (c) by one model year.

(iv) Label qualifying vehicles with the following statement: “THIS VEHICLE MEETS PHASE 2 STANDARDS AS ALLOWED UNDER 40 CFR 1037.150(c).”

(v) Small manufacturers may bank emission credits only by certifying all their vehicle families within a given averaging set to the Phase 3 standards that apply for the current model year.

(vi) The battery durability monitor requirements of § 1037.115(f) apply for vehicles subject to standards under this paragraph (c).

(35) See paragraphs (r), (t), (yu), and (aaw) of this section for additional allowances for small manufacturers.

\* \* \* \* \*

(f) ~~Testing exemption for qualifying vehicles. Tailpipe CO<sub>2</sub> emissions from battery electric vehicles, fuel cell electric vehicles, and vehicles with engines fueled with neat hydrogen are deemed to be zero. No CO<sub>2</sub>-related testing is required under this part for these vehicles.~~ ~~Electric and hydrogen fuel cell vehicles. Tailpipe emissions of regulated GHG pollutants from electric vehicles and hydrogen fuel cell vehicles are deemed to be zero. No CO<sub>2</sub>-related emission testing is required for electric vehicles or hydrogen fuel cell vehicles. Use good engineering judgment to apply other requirements of this part to electric vehicles.~~

\* \* \* \* \*

(p) ~~Credit multiplier for advanced technology. You may calculate credits you generate from vehicles certified with advanced technology as follows:If you generate credits from Phase 1 vehicles certified with advanced technology, you may~~

(1) For Phase 1 vehicles, multiply the credits by 1.50, except that you may not apply this multiplier in addition to the early-credit multiplier of paragraph (a) of this section.

(2) For model year 2026 and earlier, apply multipliers of 3.5 for plug-in hybrid electric vehicles, 4.5 for battery electric vehicles, and 5.5 for fuel cell electric vehicles; multiply these credits by 1.50, except that you may not apply this multiplier in addition to the early credit multiplier of paragraph (a) of this section. If you generate credits from model year 2027 and earlier Phase 2 vehicles certified with advanced technology, you may multiply these credits by 3.5 for plug-in hybrid electric vehicles, 4.5 for electric vehicles, and 5.5 for fuel cell vehicles calculate credits relative to the Phase 2 standard. In model year 2027, the advanced technology multiplier applies only for fuel cell electric vehicles, with credits multiplied relative to the Phase 3 standard.

\* \* \* \* \*

~~(u) Streamlined preliminary approval for trailer devices.~~ Before January 1, 2018, manufacturers of aerodynamic devices for trailers may ask for preliminary EPA approval of compliance data for their devices based on qualifying for designation under the SmartWay program based on measured  $C_dA$  values, whether or not that involves testing or other methods specified in § 1037.526. Trailer manufacturers may certify based on  $AC_dA$  values established under this paragraph (u) through model year 2020. Manufacturers must perform testing as specified in subpart F of this part for any vehicles or aerodynamic devices not qualifying for approval under this paragraph (u).

~~(v) Transitional allowances for trailers.~~ Through model year 2026, trailer manufacturers may calculate a number of trailers that are exempt from the standards and certification requirements of this part. Calculate the number of exempt box vans in a given model year by multiplying your total U.S. directed production volume of certified box vans by 0.20 and rounding to the nearest whole number; however, in no case may the number of exempted box vans be greater than 350 units in any given model year. Repeat this calculation to determine the number of non-box trailers, up to 250 annual units, that are exempt from standards and certification requirements. Perform the calculation based on your projected production volumes in the first year that standards apply; in later years, use actual production volumes from the preceding model year. Include these calculated values and your production volumes of exempt trailers in your annual production report under § 1037.250. You must apply a label meeting the requirements of 40 CFR 1068.45(a) that identifies your corporate name and states that the trailer is exempt under the provisions of § 1037.150. Unlabeled trailers will be considered in violation of 40 CFR 1068.101(a)(1).

~~(w) Roll-up doors for non-aero box vans.~~ Through model year 2023, box vans may qualify for non-aero or partial-aero standards under § 1037.107 by treating roll-up rear doors as being equivalent to rear lift-gates.

~~(x) Aerodynamic testing for trailers.~~ Section 1037.526 generally requires you to adjust  $AC_dA$  values from alternate test methods to be equivalent to measurements with the primary test method. This paragraph (x) describes approximations that we believe are consistent with good engineering judgment; however, you may not use these approximations where we determine that clear and convincing evidence shows that they would significantly overestimate actual improvements in aerodynamic performance.

~~(1) You may presume that CFD measurements at a yaw angle of  $4.5^\circ$  are equal to measurements made using the primary method, and you may use them without adjustment.~~

~~(2) You may presume that coastdown measurements at yaw angles smaller than  $\pm 4.5^\circ$  are equal to measurements made using the primary method, and you may use them without adjustment. This applies equally for device manufacturers, but it does not apply for EPA testing.~~

~~(3) You may use testing or analytical methods to adjust coastdown measurements to account for aerodynamic effects at a yaw angle of  $\pm 4.5^\circ$ . This applies for rear fairings and other devices whose performance is affected by yaw angle.~~

~~(bbx)~~ *Transition to updated GEM.* (1) Vehicle manufacturers may demonstrate compliance with Phase 2 ~~GHG-greenhouse gas~~ standards in model years 2021 through 2023 using GEM Phase 2, Version 3.0, Version 3.5.1, or Version 4.0 (incorporated by reference in §1037.810). Manufacturers may change to a different version of GEM for model years 2022 and 2023 for a given vehicle family after initially submitting an application for certification; such a change must be documented as an amendment under § 1037.225. Manufacturers may submit an end-of-year report for model year 2021 using any of the three regulatory versions of GEM, but only for demonstrating compliance with the custom-chassis standards in § 1037.105(h); such a change must be documented in the report submitted under § 1037.730. Once a manufacturer certifies a vehicle family based on GEM Version 4.0, it may not revert back to using GEM Phase 2, Version 3.0 or Version 3.5.1 for that vehicle family in any model year. (2) Vehicle manufacturers may certify for model years 2021 through 2023 based on fuel maps from engines or powertrains that were created using GEM Phase 2, Version 3.0, Version 3.5.1, or Version 4.0 (incorporated by reference in § 1037.810). Vehicle manufacturers may alternatively certify in those years based on fuel maps from powertrains that were created using GEM Phase 2, Version 3.0, GEM HIL model 3.8, or GEM Phase 2, Version 4.0 (incorporated by reference in § 1037.810). Vehicle manufacturers may continue to certify vehicles in later model years using fuel maps generated with earlier versions of GEM for model year 2024 and later vehicle families that qualify for using carryover provisions in § 1037.235(d).

(y) *Correcting credit calculations. If you notify us by October 1, 2024 that errors mistakenly decreased your balance of emission credits for 2020 or any earlier model years, you may correct the errors and recalculate the balance of emission credits after applying a 10 percent discount to the credit correction.*

## Subpart C—Certifying Vehicle Families

55. Amend § 1037.205 by revising the introductory text, paragraphs (b) introductory text, (b)(6), (e), (o), and (q) to read as follows:

### **§ 1037.205 What must I include in my application?**

This section specifies the information that must be in your application, unless we ask you to include less information under § 1037.201(c). We may require you to provide additional information to evaluate your application. References to testing and emission-data vehicles refer to testing vehicles or components to measure any quantity that serves as an input value for modeling emission rates under § ~~1037.515 or~~ 1037.520.

\* \* \* \* \*

(b) Explain how the emission control system operates. As applicable, describe in detail all system components for controlling greenhouse gas emissions, including all auxiliary emission control devices (AECDs) and all fuel-system components you will install on any production vehicle. Identify the part number of each component you describe. For this paragraph (b), treat as separate AECDs any devices that modulate or activate differently from each other. Also describe your modeling inputs as described in §§ ~~1037.515 and~~ 1037.520, with the following additional information if it applies for your vehicles:

\* \* \* \* \*

(6) If you perform powertrain testing under ~~§ 40.10367.5450~~, report both CO<sub>2</sub> and NO<sub>x</sub> emission levels corresponding to each test run.

\* \* \* \* \*

(e) Describe any test equipment and procedures that you used, including any special or alternate test procedures you used (see § 1037.501). Include information describing the procedures you used to determine C<sub>d</sub>A values as specified in §§ 1037.525 ~~through and~~ 1037.527. Describe which type of data you are using for engine fuel maps (see 40 CFR 1036.505). ~~If your trailer certification relies on approved data from device manufacturers, identify the device and device manufacturer.~~

\* \* \* \* \*

(o) Report calculated and modeled emission results as follows:

~~(1) For vocational vehicles and tractors, report modeling results~~ for ten configurations. Include modeling inputs and detailed descriptions of how they were derived. Unless we specify otherwise, include the configuration with the highest modeling result, the lowest modeling result, and the configurations with the highest projected sales.

~~(2) For trailers that demonstrate compliance with g/ton-mile emission standards as described in § 1037.515, report the CO<sub>2</sub> emission result for the configuration with the highest calculated value. If your trailer family generates or uses emission credits, also report the CO<sub>2</sub> emission results for the configuration with the lowest calculated value, and for the configuration with the highest projected sales.~~

\* \* \* \* \*

~~(q) For battery electric vehicles and plug-in hybrid electric vehicles, describe the recharging procedures and methods for determining battery performance, such as state of charge and charging capacity. Also include the certified usable battery energy for each battery durability subfamily. Include the following information for electric vehicles and fuel cell vehicles to show they meet the standards of this part:~~

~~(1) You may attest that vehicles comply with the standards of § 1037.102 instead of submitting test data.~~

~~(2) For vehicles generating credits under § 1037.616, you may attest that the vehicle meets the durability requirements described in § 1037.102(b)(3) based on an engineering analysis of measured values and other information, consistent with good engineering judgment, instead of testing at the end of the useful life. Send us your test results for work produced over the FTP and initial useable battery energy or initial fuel cell voltage. Also send us your engineering analysis describing how you meet the durability requirements if we ask for it.~~

\* \* \* \* \*

### § 1037.230—[Amended]

56. Amend § 1037.230 by removing paragraphs (a)(3) and (d)(3).

57. Amend § 1037.231 by revising paragraph (a) to read as follows:

### § 1037.231 Powertrain families.

(a) If you choose to perform powertrain testing as specified in ~~§ 40 CFR 10367.5450~~, use good engineering judgment to divide your product line into powertrain families that are expected to have similar fuel consumptions and CO<sub>2</sub> emission characteristics throughout the useful life. Your powertrain family is limited to a single model year.

\* \* \* \* \*

58. Amend § 1037.235 by revising the introductory text and paragraphs (a) and (c)(3) and removing paragraph (g)(3) to read as follows:

**§ 1037.235 Testing requirements for certification.**

This section describes the emission testing you must perform to show compliance with respect to the greenhouse gas emission standards in subpart B of this part, and to determine any input values from §§ ~~1037.515 and~~ 1037.520 that involve measured quantities.

(a) Select emission-data vehicles that represent production vehicles and components for the vehicle family consistent with the specifications in §§ 1037.205(o), ~~1037.515~~, and 1037.520. Where the test results will represent multiple vehicles or components with different emission performance, use good engineering judgment to select worst-case emission data vehicles or components. In the case of powertrain testing under ~~§ 40 CFR 10367.5450~~, select a test engine, test hybrid components, test axle and test transmission as applicable, by considering the whole range of vehicle models covered by the powertrain family and the mix of duty cycles specified in § 1037.510. If the powertrain has more than one transmission calibration, for example economy vs. performance, you may weight the results from the powertrain testing in ~~40 CFR § 10367.5450~~ by the percentage of vehicles in the family by prior model year for each configuration. This can be done, for example, through the use of survey data or based on the previous model year's sales volume. Weight the results of  $M_{\text{fuel}[\text{cycle}]}$ ,  $\frac{f_{\text{npowertrain}}}{v_{\text{powertrain}}}$ , and  $W_{[\text{cycle}]}$  from Table 2 of ~~40~~

~~CFR § 10367.5450~~ according to the percentage of vehicles in the family that use each transmission calibration.

\* \* \* \* \*

(c) \* \* \*

(3) Before we test one of your vehicles or components, we may set its adjustable parameters to any point within the ~~physically-practically~~ adjustable ranges, if applicable.

\* \* \* \* \*

(g) \* \* \*

~~(3) We may test trailers (and devices receiving preliminary approval) using the wind tunnel method described in § 1037.530. We may also test using an alternate method; however, we will determine how to appropriately correct or correlate those results to testing with the wind tunnel method.~~

\* \* \* \* \*

59. Amend § 1037.241 to read as follows:

**§ 1037.241 Demonstrating compliance with exhaust emission standards for greenhouse gas pollutants.**

(a) Compliance determinations for purposes of certification depend on whether or not you participate in the ABT program in subpart H of this part.

(1) If none of your vehicle families generate or use emission credits in a given model year, , each of your vehicle families is considered in compliance with the CO<sub>2</sub> emission standards in §§ 1037.105 ~~through 1037.107 and 1037.106~~ if all vehicle configurations in the family have calculated or modeled CO<sub>2</sub> emission rates from ~~§ 1037.515 or~~ § 1037.520 that are at or below the applicable standards. A vehicle family is deemed not to comply if any vehicle configuration in the family has a calculated or modeled CO<sub>2</sub> emission rate that is above the applicable standard.



(2) If you generate or use emission credits with one or more vehicle families in a given model year, your vehicle families within an averaging set are considered in compliance with the CO<sub>2</sub> emission standards in §§ 1037.105 ~~through 1037.107~~ and 1037.106 if the sum of positive and negative credits for all vehicle configurations in those vehicle families lead to a zero balance or a positive balance of credits, except as allowed by § 1037.745. Note that the FEL is considered to be the applicable emission standard for an individual configuration.

~~(b) For non-box trailers and non-aero box vans, your vehicle family is considered in compliance with the emission standards if all vehicle configurations in that family meet specified design standards and have TRRL values at or below the specified standard. Your family is deemed not to comply for certification if any trailer does not meet specified design standards or if any vehicle configuration in that family has a measured TRRL value above the specified standard.~~

~~(e)~~ We may require you to provide an engineering analysis showing that the performance of your emission controls will not deteriorate during the useful life with proper maintenance. If we determine that your emission controls are likely to deteriorate during the useful life, we may require you to develop and apply deterioration factors consistent with good engineering judgment. For example, you may need to apply a deterioration factor to address deterioration of battery performance for a hybrid ~~electric~~ vehicle. Where the highest useful life emissions occur between the end of useful life and at the low-hour test point, base deterioration factors for the vehicles on the difference between (or ratio of) the point at which the highest emissions occur and the low-hour test point.

## Subpart D— Testing Production Vehicles and Engines

### § 1037.310—[Removed]

60. Remove § 1037.310.

### ~~§ 1037.310—Audit procedures for trailers.~~

~~(a) We may audit trailer manufacturers to ensure that trailers are being produced to conform with the certificate of conformity. If this involves aerodynamic measurements, we will specify how to adapt the protocol described in § 1037.305 to appropriately evaluate trailer performance.~~

~~(b) We may require device manufacturers that obtain preliminary approval under § 1037.211 to perform aerodynamic testing of production samples of approved devices to ensure that the devices conform to the approved configuration.~~

61. Amend § 1037.315 by revising paragraph (a) to read as follows:

### **§ 1037.315 Audit procedures related to powertrain testing.**

(a) For vehicles certified based on powertrain testing as specified in ~~§ 40 CFR 10367.5450~~, we may apply the selective enforcement audit requirements to the powertrain. If engine manufacturers perform the powertrain testing and include those results in their certification under 40 CFR part 1036, they are responsible for selective enforcement audits related to those results. Otherwise, the certificate holder for the vehicle is responsible for the selective enforcement audit.

\* \* \* \* \*

## Subpart E—In-use Testing

62. Amend § 1037.401 by revising paragraph (b) to read as follows:

**§ 1037.401 General provisions.**

\* \* \* \* \*

(b) We may measure the drag area of a vehicle you produced after it has been placed into service. We may use any of the procedures as specified in §§ 1037.525 ~~and through~~ 1037.527 for measuring drag area. Your vehicle conforms to the regulations of this part with respect to aerodynamic performance if we measure its drag area to be at or below the maximum drag area allowed for the bin to which that configuration was certified.

**Subpart F—Test and Modeling Procedures**

63. Amend § 1037.501 by revising paragraphs (a) and (h) and removing paragraph (i) to read as follows:

**§ 1037.501 General testing and modeling provisions.**

\* \* \* \* \*

(a) Except as specified in subpart B of this part, you must demonstrate that you meet emission standards using emission modeling as described in §§ ~~1037.515 and~~ 1037.520. This modeling depends on several measured values as described in this subpart F. You may use fuel-mapping information from the engine manufacturer as described in 40 CFR 1036.535 and 1036.540, or you may use powertrain testing as described in 40 CFR § 1037.1036.5450.

\* \* \* \* \*

~~(h) Use a standard tractor for measuring aerodynamic drag of trailers. Standard tractors must be certified at Bin III (or more aerodynamic if a Bin III tractor is unavailable) for Phase 1 or Phase 2 under § 1037.520(b)(1) or (3). The standard tractor for long trailers is a Class 8 high-roof sleeper cab. The standard tractor for short trailers is a Class 7 or Class 8 high-roof day cab with a 4×2 drive-axle configuration.~~

~~(i)~~ Note that declared GEM inputs for fuel maps and aerodynamic drag area typically includes compliance margins to account for testing variability; for other measured GEM inputs, the declared values are typically the measured values without adjustment.

64. Amend § 1037.510 by:

- a. Revising paragraphs (a) introductory text, (a)(2) introductory text, and (a)(2)(iii) and (iv).
- b. In the Where statement for  $\bar{v}_{\text{moving}}$  and  $w_{[\text{cycle}]}$ , removing the text “table 1 to this section” and adding, in its place, the text “table 1 of this section”.
- c. Revising paragraphs (c)(3) and (d).

The revisions read as follows:

**§ 1037.510 Duty-cycle exhaust testing.**

\* \* \* \* \*

(a) Measure emissions by testing ~~the vehicle on a chassis dynamometer or~~ the powertrain on a powertrain dynamometer with the applicable duty cycles. Each duty cycle consists of a series of speed commands over time—variable speeds for the transient test and constant speeds for the highway cruise tests. None of these cycles include vehicle starting or warmup.

\* \* \* \* \*

(2) Perform cycle-average engine fuel mapping as described in 40 CFR 1036.540. For powertrain testing under 40 CFR § 1037.1036.5450 or § 1037.555, perform testing as

described in this paragraph (a)(2) to generate GEM inputs for each simulated vehicle configuration, and test runs representing different idle conditions. Perform testing as follows:

\* \* \* \* \*

(iii) *Drive idle*. Perform testing at a loaded idle condition for Phase 2 vocational vehicles. For engines with an adjustable warm idle speed setpoint, test at the minimum warm idle speed and the maximum warm idle speed; otherwise simply test at the engine’s warm idle speed. Warm up the powertrain as described in 40 CFR 1036.520(~~ed~~)(4). Within 60 seconds after concluding the warm-up, linearly ramp the powertrain down to zero vehicle speed over 20 seconds. Apply the brake and keep the transmission in drive (or clutch depressed for manual transmission). Stabilize the powertrain for  $(60 \pm 1)$  seconds and then sample emissions for  $(30 \pm 1)$  seconds.

(iv) *Parked idle*. Perform testing at a no-load idle condition for Phase 2 vocational vehicles. For engines with an adjustable warm idle speed setpoint, test at the minimum warm idle speed and the maximum warm idle speed; otherwise simply test at the engine’s warm idle speed. Warm up the powertrain as described in 40 CFR 1036.520(~~de~~)(4). Within 60 seconds after concluding the warm-up, linearly ramp the powertrain down to zero vehicle speed in 20 seconds. Put the transmission in park (or neutral for manual transmissions and apply the parking brake if applicable). Stabilize the powertrain for  $(180 \pm 1)$  seconds and then sample emissions for  $(600 \pm 1)$  seconds.

\* \* \* \* \*

(c) \* \* \*

\* \* \* \* \*

(3) Table 1 follows:

TABLE 1 OF PARAGRAPH (c)(3) OF § 1037.510—WEIGHTING FACTORS FOR DUTY CYCLES

	Distance-weighted			Time-weighted <sup>a</sup>			Average speed during non-idle cycles (mi/hr) <sup>b</sup>
	Transient	55 mi/hr cruise	65 mi/hr cruise	Drive idle	Parked idle	Non-idle	
Day Cabs	19 %	17 %	64 %	—	—	—	—
Sleeper Cabs	5 %	9 %	86 %	—	—	—	—
Heavy-haul Tractors	19 %	17 %	64 %	—	—	—	—
Vocational—Regional	20 %	24 %	56 %	0 %	25 %	75 %	38.41
Vocational—Multi-Purpose (2b-7)	54 %	29 %	17 %	17 %	25 %	58 %	23.18
Vocational—Multi-Purpose (8)	54 %	23 %	23 %	17 %	25 %	58 %	23.27
Vocational—Urban (2b-7)	92 %	8 %	0 %	15 %	25 %	60 %	16.25
Vocational—Urban (8)	90 %	10 %	0 %	15 %	25 %	60 %	16.51
Vocational with conventional powertrain (Phase 1 only)	42 %	21 %	37 %	—	—	—	—

Vocational Hybrid Vehicles (Phase 1 only)	75 %	9 %	16 %	—	—	—	—
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<sup>a</sup>Note that these drive idle and non-idle weighting factors do not reflect additional drive idle that occurs during the transient cycle. The transient cycle does not include any parked idle.

<sup>b</sup>These values apply even for vehicles not following the specified speed traces.

\* \* \* \* \*

(d) For highway cruise and transient testing, compare actual second-by-second vehicle speed with the speed specified in the test cycle and ensure any differences are consistent with the criteria as specified in [40 CFR § 10367.5450\(g\)\(1\)](#). If the speeds do not conform to these criteria, the test is not valid and must be repeated.

\* \* \* \* \*

**§ 1037.515—[Removed]**

65. Remove § 1037.515.

~~**§ 1037.515—Determining CO<sub>2</sub> emissions to show compliance for trailers.**~~

~~This section describes a compliance approach for trailers that is consistent with the modeling for vocational vehicles and tractors described in § 1037.520, but is simplified consistent with the smaller number of trailer parameters that affect CO<sub>2</sub> emissions. Note that the calculated CO<sub>2</sub> emission rate, *e*<sub>CO<sub>2</sub></sub>, is equivalent to the value that would result from running GEM with the same input values.~~

~~(a) *Compliance equation.* Calculate CO<sub>2</sub> emissions for demonstrating compliance with emission standards for each trailer configuration:~~

~~(1) Use the following equation:~~

~~$$e_{CO_2} = (C_1 + C_2 \cdot TRRL + C_3 \cdot \Delta C_d A + C_4 \cdot WR) \cdot C_5$$~~

~~Eq. 1037.515-1~~

~~Where:~~

~~*C<sub>1</sub>* = constant values for calculating CO<sub>2</sub> emissions from this regression equation derived from GEM, as shown in Table 1 of this section. Let *C<sub>5</sub>* = 0.988 for trailers that have automatic tire inflation systems with all wheels, and let *C<sub>5</sub>* = 0.990 for trailers that have tire pressure monitoring systems with all wheels (or a mix of the two systems); otherwise, let *C<sub>5</sub>* = 1.~~

~~*TRRL* = tire rolling resistance level as specified in paragraph (b) of this section.~~

~~*ΔC<sub>d</sub>A* = the *ΔC<sub>d</sub>A* value for the trailer as specified in paragraph (c) of this section.~~

~~*WR* = weight reduction as specified in paragraph (d) or (e) of this section.~~

~~TABLE 1 OF § 1037.515—REGRESSION COEFFICIENTS FOR CALCULATING CO<sub>2</sub> EMISSIONS~~

<del>Trailer Category</del>	<del><i>C<sub>1</sub></i></del>	<del><i>C<sub>2</sub></i></del>	<del><i>C<sub>3</sub></i></del>	<del><i>C<sub>4</sub></i></del>
<del>Long dry box van</del>	<del>76.1</del>	<del>1.67</del>	<del>-5.82</del>	<del>-0.00103</del>
<del>Long refrigerated box van</del>	<del>77.4</del>	<del>1.75</del>	<del>-5.78</del>	<del>-0.00103</del>
<del>Short dry box van</del>	<del>117.8</del>	<del>1.78</del>	<del>-9.48</del>	<del>-0.00258</del>
<del>Short refrigerated box van</del>	<del>121.1</del>	<del>1.88</del>	<del>-9.36</del>	<del>-0.00264</del>

(2) The following is an example for calculating the mass of CO<sub>2</sub> emissions,  $e_{CO_2}$ , from a long dry box van that has a tire pressure monitoring system for all wheels, an aluminum suspension assembly, aluminum floor, and is designated as Bin IV:

$$C_1 = 76.1$$

$$C_2 = 1.67$$

$$TRRL = 4.6 \text{ kg/tonne}$$

$$C_3 = -5.82$$

$$AC_{dA} = 0.7 \text{ m}^2$$

$$C_4 = -0.00103$$

$$WR = 655 \text{ lbs}$$

$$C_5 = 0.990$$

$$e_{CO_2} = (76.1 + 1.67 \cdot 4.6 + (-5.82 \cdot 0.7) + (-0.00103 \cdot 655)) \cdot 0.990$$

$$e_{CO_2} = 78.24 \text{ g/ton-mile}$$

(b) *Tire rolling resistance.* Use the procedure specified in § 1037.520(c) to determine the tire rolling resistance level for your tires. Note that you may base tire rolling resistance levels on measurements performed by tire manufacturers, as long as those measurements meet this part's specifications.

(c) *Drag area.* You may use  $AC_{dA}$  values approved under § 1037.211 for device manufacturers if your trailers are properly equipped with those devices. Determine  $AC_{dA}$  values for other trailers based on testing. Measure  $C_{dA}$  and determine  $AC_{dA}$  values as described in § 1037.526(a). You may use  $AC_{dA}$  values from one trailer configuration to represent any number of additional trailers based on worst case testing. This means that you may apply  $AC_{dA}$  values from your measurements to any trailer models of the same category with drag area at or below that of the tested configuration. For trailers in the short dry box vans and short refrigerated box vans that are not 28 feet long, apply the  $AC_{dA}$  value established for a comparable 28-foot trailer model; you may use the same devices designed for 28-foot trailers or you may adapt those devices as appropriate for the different trailer length, consistent with good engineering judgment. For example, 48-foot trailers may use longer side skirts than the skirts that were tested with a 28-foot trailer. Trailer and device manufacturers may seek preliminary approval for these adaptations. Determine bin levels based on  $AC_{dA}$  test results as described in the following table:

TABLE 2 OF § 1037.515 — BIN DETERMINATIONS FOR TRAILERS BASED ON AERODYNAMIC TEST RESULTS ( $AC_{dA}$  in  $\text{m}^2$ )

If a trailer's measured $AC_{dA}$ is ...	designate the trailer as ...	and use the following value for $AC_{dA}$
$\leq 0.09$	Bin I	0.0
0.10—0.39	Bin II	0.1
0.40—0.69	Bin III	0.4
0.70—0.99	Bin IV	0.7
1.00—1.39	Bin V	1.0
1.40—1.79	Bin VI	1.4
$\geq 1.80$	Bin VII	1.8

(d) *Weight reduction.* Determine weight reduction for a trailer configuration by summing all applicable values, as follows:

(1) Determine weight reduction for using lightweight materials for wheels as described in § 1037.520(e).

(2) Apply weight reductions for other components made with light weight materials as shown in the following table:

TABLE 3 OF § 1037.515—WEIGHT REDUCTIONS FOR TRAILERS (POUNDS)

Component	Material	Weight reduction (pounds)
Structure for Suspension Assembly <sup>a</sup>	Aluminum	280
Hub and Drum (per axle)	Aluminum	80
Floor <sup>b</sup>	Aluminum	375
Floor <sup>b</sup>	Composite (wood and plastic)	245
Floor Crossmembers <sup>b</sup>	Aluminum	250
Landing Gear	Aluminum	50
Rear Door	Aluminum	187
Rear Door Surround	Aluminum	150
Roof Bows	Aluminum	100
Side Posts	Aluminum	300
Slider Box	Aluminum	150
Upper Coupler Assembly	Aluminum	430

<sup>a</sup>For tandem axle suspension sub frames made of aluminum, apply a weight reduction of 280 pounds. Use good engineering judgment to estimate a weight reduction for using aluminum sub frames with other axle configurations.

<sup>b</sup>Calculate a smaller weight reduction for short trailers by multiplying the indicated values by 0.528 (28/53).

- (e) *Off cycle*. You may apply the off cycle provisions of § 1037.610 to trailers as follows:
- (1) You may account for weight reduction based on measured values instead of using paragraph (d) of this section. Quantify the weight reduction by measuring the weight of a trailer in a certified configuration and comparing it to the weight of an equivalent trailer without weight reduction technologies. This qualifies as A to B testing under § 1037.610. Use good engineering judgment to select an equivalent trailer representing a baseline configuration. Use the calculated weight reduction in Eq. 1037.515-1 to calculate the trailer's CO<sub>2</sub> emission rate.
  - (2) If your off cycle technology reduces emissions in a way that is proportional to measured emissions as described in § 1037.610(b)(1), multiply the trailer's CO<sub>2</sub> emission rate by the appropriate improvement factor.
  - (3) If your off cycle technology does not yield emission reductions that are proportional to measured emissions, as described in § 1037.610(b)(2), calculate an adjusted CO<sub>2</sub> emission rate for your trailers by subtracting the appropriate off cycle credit.
  - (4) Note that these off cycle provisions do not apply for trailers subject to design standards.

66. Amend § 1037.520 by:

- a. Revising the introductory text and paragraphs (a)(2) introductory text, (b)(3), and (e)(1).

b. In paragraph (e)(3), removing the text “PHASE 2 VOCATIONAL VEHICLES” and adding, in its place, the text “PHASE 2 AND PHASE 3 VOCATIONAL VEHICLES”.

c. Revising paragraphs (g)(4), and (j)(1).

The revisions read as follows:

**§ 1037.520 Modeling CO<sub>2</sub> emissions to show compliance for vocational vehicles and tractors.**

This section describes how to use the Greenhouse gas Emissions Model (GEM) (incorporated by reference in § 1037.810) to show compliance with the CO<sub>2</sub> standards of §§ 1037.105 and 1037.106 for vocational vehicles and tractors. Use GEM version 2.0.1 to demonstrate compliance with Phase 1 standards; use GEM Phase 2, Version 4.0 to demonstrate compliance with Phase 2 and Phase 3 standards. Use good engineering judgment when demonstrating compliance using GEM. ~~See § 1037.515 for calculation procedures for demonstrating compliance with trailer standards.~~

(a) \* \* \*

(2) For Phase 2 and Phase 3 vehicles, the GEM inputs described in paragraphs (a)(1)(i) through (v) of this section continue to apply. Note that the provisions in this part related to vehicle speed limiters and automatic engine shutdown systems are available for vocational vehicles in Phase 2 and Phase 3. The rest of this section describes additional GEM inputs for demonstrating compliance with Phase 2 and Phase 3 standards. Simplified versions of GEM apply for limited circumstances as follows:

(b) \* \* \*

(3) For Phase 2 and Phase 3 tractors other than heavy-haul tractors, determine bin levels and C<sub>d</sub>A inputs as follows:

(i) Determine bin levels for high-roof tractors based on aerodynamic test results as specified in § 1037.525 and summarized in the following table:

TABLE 3 TO PARAGRAPH (b)(3)(i) OF § 1037.520—BIN DETERMINATIONS FOR PHASE 2 AND PHASE 3 HIGH-ROOF TRACTORS BASED ON AERODYNAMIC TEST RESULTS (C<sub>d</sub>A in m<sup>2</sup>)

Tractor type	Bin I	Bin II	Bin III	Bin IV	Bin V	Bin VI	Bin VII
Day Cabs	≥ 7.2	6.6-7.1	6.0-6.5	5.5-5.9	5.0-5.4	4.5-4.9	≤ 4.4
Sleeper Cabs	≥ 6.9	6.3-6.8	5.7-6.2	5.2-5.6	4.7-5.1	4.2-4.6	≤ 4.1

(ii) For low- and mid-roof tractors, you may either use the same bin level that applies for an equivalent high-roof tractor as shown in Table 3 of this section, or you may determine your bin level based on aerodynamic test results as described in Table 4 of this section.

TABLE 4 TO PARAGRAPH (b)(3)(ii) OF § 1037.520—BIN DETERMINATIONS FOR PHASE 2 AND PHASE 3 LOW-ROOF AND MID-ROOF TRACTORS BASED ON AERODYNAMIC TEST RESULTS (C<sub>d</sub>A in m<sup>2</sup>)

Tractor type	Bin I	Bin II	Bin III	Bin IV	Bin V	Bin VI	Bin VII
Low-Roof Cabs	≥ 5.4	4.9-5.3	4.5-4.8	4.1-4.4	3.8-4.0	3.5-3.7	≤ 3.4
Mid-Roof Cabs	≥ 5.9	5.5-5.8	5.1-5.4	4.7-5.0	4.4-4.6	4.1-4.3	≤ 4.0

(iii) Determine the C<sub>d</sub>A input according to the tractor’s bin level as described in the following table:

TABLE 5 TO PARAGRAPH (b)(3)(iii) OF § 1037.520—PHASE 2 AND PHASE 3 CaA TRACTOR INPUTS BASED ON BIN LEVEL

Tractor type	Bin I	Bin II	Bin III	Bin IV	Bin V	Bin VI	Bin VII
High-Roof Day Cabs	7.45	6.85	6.25	5.70	5.20	4.70	4.20
High-Roof Sleeper Cabs	7.15	6.55	5.95	5.40	4.90	4.40	3.90
Low-Roof Cabs	6.00	5.60	5.15	4.75	4.40	4.10	3.80
Mid-Roof Cabs	7.00	6.65	6.25	5.85	5.50	5.20	4.90

\* \* \* \* \*

(e) \* \* \*

(1) Vehicle weight reduction inputs for wheels are specified relative to dual-wide tires with conventional steel wheels. For purposes of this paragraph (e)(1), an aluminum alloy qualifies as light-weight if a dual-wide drive wheel made from this material weighs at least 21 pounds less than a comparable conventional steel wheel. The inputs are listed in Table 6 of this section. For example, a tractor or vocational vehicle with aluminum steer wheels and eight (4×2) dual-wide aluminum drive wheels would have an input of 210 pounds (2×21 + 8×21).

TABLE 6 TO § 1037.520—WHEEL-RELATED WEIGHT REDUCTIONS

<u>Weight-reduction technology</u> <u>Tire type</u>	<u>Material</u>	<u>Weight reduction— Phase 1</u> <u>(#-pounds per wheel)</u>	<u>Weight reduction— Phase 2 and Phase 3</u> <u>(#-pounds per wheel)</u>
Wide-Base Single Drive Tire with . . . <sup>a</sup>	Steel Wheel	84	84
	Aluminum Wheel	139	147
	Light-Weight Aluminum Alloy Wheel	147	147
Steer Tire <u>or</u> ; Dual-wide Drive Tire, <u>or</u> Dual-wide Trailer Tire with . . .	High-Strength Steel Wheel	8	8
	Aluminum Wheel	21	25
	Light-Weight Aluminum Alloy Wheel	30	25

<sup>a</sup>The weight reduction for wide-base tires accounts for reduced tire weight relative to dual-wide tires.

\* \* \* \* \*

(3) Weight-reduction inputs for vocational-vehicle components other than wheels are specified in the following table:

TABLE 8 TO § 1037.520—NONWHEEL-RELATED WEIGHT REDUCTIONS FROM ALTERNATIVE MATERIALS FOR PHASE 2 AND PHASE 3 VOCATIONAL VEHICLES (POUNDS)<sup>A</sup>

Component	Material	Vehicle type		
		Light HDV	Medium HDV <sup>b</sup>	Heavy HDV
Axle Hubs - Non-Drive	Aluminum		40	40
Axle Hubs - Non-Drive	High Strength Steel		5	5
Axle - Non-Drive	Aluminum		60	60
Axle - Non-Drive	High Strength Steel		15	15
Brake Drums - Non-Drive	Aluminum		60	60
Brake Drums - Non-Drive	High Strength Steel		42	42
Axle Hubs – Drive	Aluminum		40	80



Axle Hubs – Drive	High Strength Steel	10	20	
Brake Drums - Drive	Aluminum	70	140	
Brake Drums - Drive	High Strength Steel	37	74	
Suspension Brackets, Hangers	Aluminum	67	100	
Suspension Brackets, Hangers	High Strength Steel	20	30	
Crossmember – Cab	Aluminum	10	15	15
Crossmember – Cab	High Strength Steel	2	5	5
Crossmember - Non-Suspension	Aluminum	15	15	15
Crossmember - Non-Suspension	High Strength Steel	5	5	5
Crossmember -Suspension	Aluminum	15	25	25
Crossmember -Suspension	High Strength Steel	6	6	6
Driveshaft	Aluminum	12	40	50
Driveshaft	High Strength Steel	5	10	12
Frame Rails	Aluminum	120	300	440
Frame Rails	High Strength Steel	40	40	87

<sup>a</sup>Weight-reduction values apply per vehicle unless otherwise noted.

<sup>b</sup>For Medium HDV with 6×4 or 6×2 axle configurations, use the values for Heavy HDV.

\* \* \* \* \*

(g) \* \* \*

(4) GEM inputs associated with powertrain testing include powertrain family, transmission calibration identifier, test data from [40 CFR§ 10367.5450](#), and the powertrain test configuration (dynamometer connected to transmission output or wheel hub). You do not need to identify or provide inputs for transmission gear ratios, fuel map data, or engine torque curves, which would otherwise be required under paragraph (f) of this section.

\* \* \* \* \*

(j) \* \* \* \* \*

(1) *Intelligent controls*. Enter 2 for tractors with predictive cruise control. This includes any cruise control system that incorporates satellite-based global-positioning data for controlling operator demand. For tractors without predictive cruise control and for all vocational vehicles, enter 1.5 if they have neutral coasting or full cylinder deactivation when coasting, unless good engineering judgment indicates that a lower percentage should apply.

\* \* \* \* \*

67. Amend § 1037.525 by revising paragraphs (a) introductory text, (b)(1), (4), and (5), (c)(1) introductory text, and (c)(2) introductory text to read as follows:

**§ 1037.525 Aerodynamic measurements for tractors.**

\* \* \* \* \*

(a) *General provisions*. The GEM input for a tractor’s aerodynamic performance is a  $C_d$  value for Phase 1 and a  $C_dA$  value for Phase 2 and Phase 3. The input value is measured or calculated for a tractor in a specific test configuration with a trailer, such as a high-roof tractor with a box van meeting the requirements for the standard trailer.

\* \* \* \* \*

(b) \* \* \*

(1) Determine the functional relationship between your alternate method and coastdown testing. Specify this functional relationship as  $F_{alt-aero}$  for a given alternate drag measurement method. The effective yaw angle,  $\psi_{eff}$ , is assumed to be zero degrees for Phase 1. For Phase 2 and Phase 3, determine  $\psi_{eff}$  from coastdown test results using the following equation:

$$F_{alt-aero} = \frac{C_d A_{coastdown}(\psi_{eff})}{C_d A_{alt}(\psi_{eff})}$$

Eq. 1037.525-1

Where:

$C_d A_{coastdown}(\psi_{eff})$  = the average drag area measured during coastdown at an effective yaw angle,  $\psi_{eff}$ .

$C_d A_{alt}(\psi_{eff})$  = the average drag area calculated from an alternate drag measurement method at an effective yaw angle,  $\psi_{eff}$ .

\* \* \* \* \*

(4) Measure the drag area using your alternate method for a Phase 2 and Phase 3 tractor used to determine  $F_{alt-aero}$  with testing at yaw angles of  $0^\circ$ ,  $\pm 1^\circ$ ,  $\pm 3^\circ$ ,  $\pm 4.5^\circ$ ,  $\pm 6^\circ$ , and  $\pm 9^\circ$  (you may include additional angles), using direction conventions described in Figure 2 of SAE J1252 (incorporated by reference in § 1037.810). Also, determine the drag area at the coastdown effective yaw angle,  $C_d A_{alt}(\psi_{eff})$ , by taking the average drag area at  $\psi_{eff}$  and  $-\psi_{eff}$  for your vehicle using the same alternate method.

(5) For Phase 2 and Phase 3 testing, determine separate values of  $F_{alt-aero}$  for at least one high-roof day cab and one high-roof sleeper cab for model year 2021, at least two high-roof day cabs and two high-roof sleeper cabs for model year 2024, and at least three high-roof day cabs and three high-roof sleeper cabs for model year 2027. These test requirements are cumulative; for example, you may meet these requirements by testing two vehicles to support model year 2021 certification and four additional vehicles to support model year 2023 certification. For any untested tractor models, apply the value of  $F_{alt-aero}$  from the tested tractor model that best represents the aerodynamic characteristics of the untested tractor model, consistent with good engineering judgment. Testing under this paragraph (b)(5) continues to be valid for later model years until you change the tractor model in a way that causes the test results to no longer represent production vehicles. You must also determine unique values of  $F_{alt-aero}$  for low-roof and mid-roof tractors if you determine  $C_d A$  values based on low or mid-roof tractor testing as shown in Table 4 of § 1037.520. For Phase 1 testing, if good engineering judgment allows it, you may calculate a single, constant value of  $F_{alt-aero}$  for your whole product line by dividing the coastdown drag area,  $C_d A_{coastdown}$ , by drag area from your alternate method,  $C_d A_{alt}$ .

\* \* \* \* \*

(c) \* \* \*

(1) Apply the following method for all Phase 2 and Phase 3 testing with an alternate method:

\* \* \* \* \*

(2) Apply the following method for Phase 2 and Phase 3 coastdown testing other than coastdown testing used to establish  $F_{alt-aero}$ :

\* \* \* \* \*

**§ 1037.526—[Removed]**

68. Remove § 1037.526.

**~~§ 1037.526—Aerodynamic measurements for trailers.~~**

~~This section describes a methodology for determining aerodynamic drag area,  $C_dA$  for use in determining input values for box vans as described in §§ 1037.515 and 1037.520.~~

~~(a) A trailer's aerodynamic performance for demonstrating compliance with standards is based on a  $\Delta C_dA$  value relative to a baseline trailer. Determine these  $\Delta C_dA$  values by performing A to B testing, as follows:~~

~~(1) Determine a baseline  $C_dA$  value for a standard tractor pulling a test trailer representing a production configuration; use a 53-foot test trailer to represent long trailers and a 28-foot test trailer to represent short trailers. Repeat this testing with the same tractor and the applicable baseline trailer. For testing long trailers, the baseline trailer is a trailer meeting the specifications for a Phase 1 standard trailer in § 1037.501(g)(1); for testing refrigerated box vans, use a baseline trailer with an installed HVAC unit that properly represents a baseline configuration correlated with the production configuration. For testing short trailers, use a 28-foot baseline trailer with a single axle that meets the same specifications as the Phase 1 standard trailer, except as needed to accommodate the reduced trailer length.~~

~~(2) Use good engineering judgment to perform paired tests that accurately demonstrate the reduction in aerodynamic drag associated with the improved design. For example, the gap dimension should be the same for all paired tests, and effective yaw angle between paired tests should differ by no more than 1.0°.~~

~~(3) Measure  $C_dA$  in  $m^2$  to two decimal places. Calculate  $\Delta C_dA$  by subtracting the drag area for the test trailer from the drag area for the baseline trailer.~~

~~(b) The default method for measuring is the wind tunnel procedure as specified in § 1037.530. You may test using alternate methods as follows:~~

~~(1) If we approve it in advance, you may instead use one of the alternate methods specified in §§ 1037.528 through 1037.532, consistent with good engineering judgment, which may require that you adjust your test results from the alternate test method to correlate with the primary method. If you request our approval to determine  $\Delta C_dA$  using an alternate method, you must submit additional information as described in paragraph (d) of this section.~~

~~(2) The principles of 40 CFR 1065.10(c)(1) apply for aerodynamic test methods. Specifically, we may require that you use coastdown measurements if we determine that certain technologies are not suited to evaluation with wind tunnel testing or CFD, such as nonrigid materials whose physical characteristics change in scaled-model testing. You may similarly reference 40 CFR 1065.10(c)(1) in your request to use coastdown testing as an alternate method.~~

~~(c) The following provisions apply for combining multiple devices under this section for the purpose of certifying trailers:~~

~~(1) If the device manufacturer establishes a  $\Delta C_dA$  value in a single test with multiple aerodynamic devices installed, trailer manufacturers may use that  $\Delta C_dA$  value directly for the same combination of aerodynamic devices installed on production trailers.~~

~~(2) Trailer manufacturers may combine  $\Delta C_dA$  values for aerodynamic devices that are not tested together, as long as each device does not significantly impair the effectiveness of another, consistent with good engineering judgment. To approximate the overall benefit of multiple devices, calculate a composite  $\Delta C_dA$  value for multiple aerodynamic devices by applying the full  $\Delta C_dA$  value for the device with the greatest aerodynamic improvement,~~

~~adding the second highest  $\Delta C_dA$  value multiplied by 0.9, and adding any other  $\Delta C_dA$  values multiplied by 0.8.~~

~~(d) You must send us a description of your plan to perform testing under this section before you start testing. We will evaluate whether plans for wind tunnel testing meet the specifications of § 1037.530, and will tell you if you may or must use any other method to determine drag coefficients. We will approve your request to use an alternate method if you show that your procedures produce data that are the same as or better than wind tunnel testing with respect to repeatability and unbiased correlation. Note that the correlation is not considered to be biased if there is a bias before correction, but you apply a correction to remove the bias. Send your testing plan to the Designated Compliance Officer. Keep records of the information specified in this paragraph (d). Unless we specify otherwise, include this information with your request. You must provide any information we require to evaluate whether you may apply the provisions of this section. Include additional information related to your alternate method as described in §§ 1037.528 through 1037.534.~~

69. Revise § 1037.527 to read as follows:

#### **§ 1037.527 Aerodynamic measurements for vocational vehicles.**

~~This section describes a methodology for determining aerodynamic drag area,  $C_dA$ , for use in determining input values for vocational vehicles as described in § 1037.520. This measurement is optional.~~

~~(a) Determine  $\Delta C_dA$  values by performing A to B testing as described for trailers in § 1037.526, with any appropriate adjustments, consistent with good engineering judgment.~~

~~(b) [Reserved] This section describes a methodology for determining vocational vehicle aerodynamic input values for as described in § 1037.520. This measurement is optional. A vocational vehicle's aerodynamic performance is based on a  $\Delta C_dA$  value relative to a baseline vehicle. Determine a  $\Delta C_dA$  value by performing A to B testing as follows:~~

~~(a) Determine a baseline  $C_dA$  value for a vehicle representing a production configuration without the aerodynamic improvement. Repeat this testing and measure  $C_dA$  for a vehicle with the improved aerodynamic design.~~

~~(b) Use good engineering judgment to perform paired tests that accurately demonstrate the reduction in aerodynamic drag associated with the improved design.~~

~~(c) Measure  $C_dA$  in  $m^2$  to two decimal places. Calculate  $\Delta C_dA$  by subtracting the drag area for the test vehicle from the drag area for the baseline vehicle.~~

70. Amend § 1037.528 by:

a. Revising the introductory text and paragraphs (b) introductory text and (h)(5)(iv).

b. Removing paragraph (h)(7).

c. Redesignating paragraphs (h)(8) through (12) as paragraphs (h)(7) through (11).

d. Revising redesignated paragraph (h)(10).

The revisions read as follows:

#### **§ 1037.528 Coastdown procedures for calculating drag area ( $C_dA$ ).**

The coastdown procedures in this section describe how to calculate drag area,  $C_dA$ , for Phase 2 and Phase 3 tractors, ~~trailers~~, and vocational vehicles, subject to the provisions of §§ 1037.525 through and 1037.527. These procedures are considered the reference method for tractors, ~~but an alternate method for trailers~~. Follow the provisions of Sections 1 through 9 of SAE J2263 (incorporated by reference in § 1037.810), with the clarifications and exceptions described in this

section. Several of these exceptions are from SAE J1263 (incorporated by reference in § 1037.810). The coastdown procedures in 40 CFR 1066.310 apply instead of the provisions of this section for Phase 1 tractors.

\* \* \* \* \*

(b) To determine  $C_{dA}$  values for a tractor, perform coastdown testing with a tractor-trailer combination using the manufacturer's tractor and a standard trailer. ~~To determine  $C_{dA}$  values for a trailer, perform coastdown testing with a tractor trailer combination using a standard tractor.~~

Prepare the vehicles tractors and trailers for testing as follows:

\* \* \* \* \*

(h) \* \* \*

(5) \* \* \*

(iv) Calculate  $\Delta F_{\text{spin}}$  using the following equation:

$$\Delta F_{\text{spin}} = F_{\text{spinhi}} - F_{\text{spinlo}}$$

Eq. 1037.528-10

Example:

$$\Delta F_{\text{spin}} = 129.7 - 52.7$$

$$= 77.0 \text{ N} \quad \Delta F_{\text{spin}} = 77.0 \text{ N}$$

\* \* \* \* \*

~~(7) For trailer testing, determine  $\Delta F_{\text{TRR}}$  using a default value adjusted to the ambient temperature instead of performing a rolling resistance test, as follows:~~

$$\Delta F_{\text{TRR}} = \Delta F_{\text{TRR,def}} [1 + 0.006 \cdot (24 - \bar{T}_{\text{coast}})]$$

Eq. 1037.528-15

Where:

$\Delta F_{\text{TRR,def}}$  = default rolling resistance force speed adjustment; Use 215 N for long box vans and 150 N for short box vans.

$\bar{T}_{\text{coast}}$  = the average ambient temperature during both low and high speed segments.

Example:

$$\Delta F_{\text{TRR,def}} = 215 \text{ N}$$

$$\bar{T}_{\text{coast}} = 25.5 \text{ }^\circ\text{C}$$

$$F_{\text{TRR}} = 215 \cdot [1 + 0.006 \cdot (24 - 25.5)] = 213.1 \text{ N}$$

(10+) Calculate drag area,  $C_{dA}$ , in  $\text{m}^2$  for each high-speed segment using the following equation, expressed to at least three decimal places:

$$C_{dA} = \frac{2 \cdot (F_{\text{hi}} - F_{\text{lo,pair}} - \Delta F_{\text{spin}} - \Delta F_{\text{TRR}})}{(\bar{v}_{\text{air,hi}}^2 - \bar{v}_{\text{air,lo,pair}}^2)} \cdot \frac{R \cdot \bar{T}}{\bar{p}_{\text{act}}}$$

Eq. 1037.528-16

Where:

$F_{\text{hi}}$  = road load force at high speed determined from Eq. 1037.528-7.

$F_{\text{lo,pair}}$  = the average of  $F_{\text{lo}}$  values for a pair of opposite direction runs calculated as described in paragraph (h)(9) of this section.

$\Delta F_{\text{spin}}$  = the difference in drive-axle spin loss force between high-speed and low-speed coastdown segments. This is described in paragraph (h)(5) of this section for tractor testing.

~~Let  $\Delta F_{\text{spin}} = 110 \text{ N}$  for trailer testing.~~

$\Delta F_{\text{TRR}}$  = the difference in tire rolling resistance force between high-speed and low-speed coastdown segments as described in paragraphs (h)(6) ~~or (7)~~ of this section.

$\bar{v}_{\text{air,lo,pair}}^2$  = the average of  $\bar{v}_{\text{air,lo}}^2$  values for a pair of opposite direction runs calculated as described in paragraph (h)(9) of this section.

$R$  = specific gas constant = 287.058 J/(kg·K).

$\bar{T}$  = mean air temperature expressed to at least one decimal Place.

$\bar{p}_{\text{act}}$  = mean absolute air pressure expressed to at least one decimal place.

*Example:*

$F_{\text{hi}} = 4645.5 \text{ N}$

$F_{\text{lo,pair}} = 1005.0 \text{ N}$

$\Delta F_{\text{spin}} = 77.0 \text{ N}$

$\Delta F_{\text{TRR}} = 187.4 \text{ N}$

$\bar{v}_{\text{air,hi}}^2 = 933.4 \text{ m}^2/\text{s}^2$

$\bar{v}_{\text{air,lo,pair}}^2 = 43.12 \text{ m}^2/\text{s}^2$

$R = 287.058 \text{ J}/(\text{kg}\cdot\text{K})$

$\bar{T} = 285.97 \text{ K}$

$\bar{p}_{\text{act}} = 101.727 \text{ kPa} = 101727 \text{ Pa}$

$$C_{dA} = \frac{2 \cdot (4640.5 - 1005.0 - 77.0 - 187.4)}{(933.4 - 43.12)} \cdot \frac{287.058 \cdot 285.97}{101727}$$

$$C_{dA} = 6.120 \text{ m}^2$$

\* \* \* \* \*

71. Amend § 1037.530 by revising the introductory text and paragraphs (a) introductory text, (c), and (d) introductory text to read as follows:

**§ 1037.530 Wind-tunnel procedures for calculating drag area ( $C_{dA}$ ).**

The wind-tunnel procedure specified in this section is ~~considered to be the primary procedure for trailers, but is~~ an alternate procedure for tractors.

(a) You may measure drag areas consistent with published SAE procedures as described in this section using any wind tunnel recognized by the Subsonic Aerodynamic Testing Association, subject to the provisions of §§ 1037.525 ~~through and~~ 1037.527. If your wind tunnel does not meet the specifications described in this section, you may ask us to approve it as an alternate method under § 1037.525(d) ~~or § 1037.526(d)~~. All wind tunnels and wind tunnel tests must meet the specifications described in SAE J1252 (incorporated by reference in § 1037.810), with the following exceptions and additional provisions:

\* \* \* \* \*

(c) To determine  $C_{dA}$  values for certifying tractors, perform wind-tunnel testing with a tractor-trailer combination using the manufacturer's tractor and a standard trailer. ~~To determine  $C_{dA}$  values for certifying trailers, perform wind-tunnel testing with a tractor-trailer combination using a standard tractor.~~ Use a moving/rolling floor if the facility has one. For Phase 1 tractors, conduct the wind tunnel tests at a zero yaw angle. For Phase 2 and Phase 3 vehicles, conduct the wind tunnel tests by measuring the drag area at yaw angles of +4.5° and -4.5° and calculating the average of those two values.

(d) In your request to use wind-tunnel testing for tractors, ~~or in your application for certification for trailers,~~ describe how you meet all the specifications that apply under this section, using terminology consistent with SAE J1594 (incorporated by reference in § 1037.810). If you request our approval to use wind-tunnel testing even though you do not meet all the

specifications of this section, describe how your method nevertheless qualifies as an alternate method under § 1037.525(d) ~~or 1037.526(d)~~ and include all the following information:

\* \* \* \* \*

72. Amend § 1037.532 by revising the introductory text and paragraphs (a) introductory text, (b), and (c) introductory text to read as follows:

**§ 1037.532 Using computational fluid dynamics to calculate drag area ( $C_dA$ ).**

This section describes how to use commercially available computational fluid dynamics (CFD) software to determine  $C_dA$  values, subject to the provisions of §§ 1037.525 ~~through and~~ 1037.527. This is considered to be an alternate method for ~~both tractors and trailers~~.

(a) For Phase 2 ~~and Phase 3~~ vehicles, use SAE J2966 (incorporated by reference in § 1037.810), with the following clarifications and exceptions:

\* \* \* \* \*

(b) For Phase 1 tractors, apply the procedures as specified in paragraphs (c) through (f) of this section. Paragraphs (c) through (f) of section apply for Phase 2 ~~and Phase 3~~ vehicles only as specified in paragraph (a) of this section.

(c) To determine  $C_dA$  values for certifying a tractor, perform CFD modeling based on a tractor-trailer combination using the manufacturer's tractor and a standard trailer. ~~To determine  $C_dA$  values for certifying a trailer, perform CFD modeling based on a tractor-trailer combination using a standard tractor.~~ Perform all CFD modeling as follows:

\* \* \* \* \*

73. Amend § 1037.540 by:

- a. Revising the introductory text and paragraphs (c)(2) and (5), (d)(4), and (f) introductory text.
- b. In paragraph (f)(3), by removing the text “the approved utility factor curve” and adding, in its place, the text “the utility factor curve in appendix E of this part”.

The revisions read as follows:

**§ 1037.540 Special procedures for testing vehicles with hybrid power take-off.**

This section describes optional procedures for quantifying the reduction in greenhouse gas emissions for vehicles as a result of running power take-off (PTO) devices with a hybrid energy delivery system. See ~~40 CFR~~ § 10367.5450 for powertrain testing requirements that apply for drivetrain hybrid systems. The procedures are written to test the PTO by ensuring that the engine produces all of the energy with no net change in stored energy (charge-sustaining), and for plug-in hybrid ~~electric~~ vehicles, also allowing for drawing down the stored energy (charge-depleting). The full charge-sustaining test for the hybrid vehicle is from a fully charged rechargeable energy storage system (RESS) to a depleted RESS and then back to a fully charged RESS. You must include all hardware for the PTO system. You may ask us to modify the provisions of this section to allow testing hybrid vehicles ~~that use a technology other than batteries for storing energy other than battery electric hybrids~~, consistent with good engineering judgment. For plug-in hybrid ~~electric vehicles~~, use a utility factor to properly weight charge-sustaining and charge-depleting operation as described in paragraph (f)(3) of this section.

\* \* \* \* \*

(c) \* \* \*

(2) Prepare the vehicle for testing by operating it as needed to stabilize the RESS at a full state of charge (or equivalent for vehicles that use a technology other than batteries for storing energy non-electric RESS).

\* \* \* \* \*

(5) Operate the vehicle over one or both of the denormalized PTO duty cycles without turning the vehicle off, until the engine starts and then shuts down. This may require running multiple repeats of the PTO duty cycles. For ~~non-PHEV~~ systems that are not plug-in hybrid systems, the test cycle is completed once the engine shuts down. For plug-in hybrid systems, continue running until the PTO hybrid is running in a charge-sustaining mode such that the “End of Test” requirements defined in 40 CFR 1066.501 are met. Measure emissions as described in paragraph (b)(7) of this section. Use good engineering judgment to minimize the variability in testing between the two types of vehicles.

\* \* \* \* \*

(d) \* \* \*

(4) Divide the total PTO operating time from paragraph (d)(3) of this section by a conversion factor of 0.0144 hr/mi for Phase 1 and 0.0217 hr/mi for Phase 2 and Phase 3 to determine the equivalent distance driven. The conversion factors are based on estimates of average vehicle speed and PTO operating time as a percentage of total engine operating time; the Phase 2 and Phase 3 conversion factor is calculated from an average speed of 27.1 mi/hr and PTO operation 37 % of engine operating time, as follows:

$$Factor = \frac{37\%}{(100\% - 37\%) \cdot 27.1\text{mi/hr}} = 0.0217\text{hr/mi}$$

\* \* \* \* \*

(f) For Phase 2 and Phase 3, calculate the delta PTO fuel results for input into GEM during vehicle certification as follows:

\* \* \* \* \*

**§1037.550—[Removed]**

74. Remove § 1037.550.

75. Amend § 1037.551 by revising the introductory text and paragraphs (b) and (c) to read as follows:

**§ 1037.551 Engine-based simulation of powertrain testing.**

~~40 CFR Section 10367.5450~~ describes how to measure fuel consumption over specific duty cycles with an engine coupled to a transmission; ~~40 CFR § 10367.5450~~(a)(5) describes how to create equivalent duty cycles for repeating those same measurements with just the engine. This § 1037.551 describes how to perform this engine testing to simulate the powertrain test. These engine-based measurements may be used for selective enforcement audits as described in § 1037.301, as long as the test engine’s operation represents the engine operation observed in the powertrain test. If we use this approach for confirmatory testing, when making compliance determinations, we will consider the uncertainty associated with this approach relative to full powertrain testing. Use of this approach for engine SEAs is optional for engine manufacturers.

\* \* \* \* \*

(b) Operate the engine over the applicable engine duty cycles corresponding to the vehicle cycles specified in § 1037.510(a)(2) for powertrain testing over the applicable vehicle simulations described in ~~40 CFR § 10367.5450~~(j). Warm up the engine to prepare for the transient test or one of the highway cruise cycles by operating it one time over one of the simulations of the



corresponding duty cycle. Warm up the engine to prepare for the idle test by operating it over a simulation of the 65-mi/hr highway cruise cycle for 600 seconds. Within 60 seconds after concluding the warm up cycle, start emission sampling while the engine operates over the duty cycle. You may perform any number of test runs directly in succession once the engine is warmed up. Perform cycle validation as described in 40 CFR 1065.514 for engine speed, torque, and power.

(c) Calculate the mass of fuel consumed as described in ~~40 CFR § 1036.5450~~(n) and (o). Correct each measured value for the test fuel's mass-specific net energy content as described in 40 CFR 1036.550. Use these corrected values to determine whether the engine's emission levels conform to the declared fuel-consumption rates from the powertrain test.

76. Amend § 1037.555 by revising the introductory text to read as follows:

**§ 1037.555 Special procedures for testing Phase 1 hybrid systems.**

This section describes a powertrain testing procedure for simulating a chassis test with a pre-transmission or post-transmission hybrid system to perform A to B testing of Phase 1 vehicles. These procedures may also be used to perform A to B testing with non-hybrid systems. See ~~40 CFR § 1037.1036.5450~~ for Phase 2 and Phase 3 hybrid systems.

\* \* \* \* \*

77. Amend § 1037.560 by revising paragraph (e)(2) to read as follows:

**§ 1037.560 Axle efficiency test.**

\* \* \* \* \*

(e) \* \* \*

(2) Maintain gear oil temperature at (81 to 83) °C. You may alternatively specify a lower range by shifting both temperatures down by the same amount for all test points or on a test point by test point basis. We will test your axle assembly using the same temperature range you specify for your testing. You may use an external gear oil conditioning system, as long as it does not affect measured values.

\* \* \* \* \*

**Subpart G—Special Compliance Provisions**

78. Amend § 1037.601 by revising paragraph (b) to read as follows:

**§ 1037.601 General compliance provisions.**

\* \* \* \* \*

(b) Vehicles exempted from the applicable standards of 40 CFR part 86 or part 1036 other than glider vehicles are exempt from the standards of this part without request. Similarly, vehicles other than glider vehicles are exempt without request if the installed engine is exempted from the applicable standards in 40 CFR part 86 or part 1036.

\* \* \* \* \*

79. Amend § 1037.610 by revising paragraph (f)(2) to read as follows:

**§ 1037.610 Vehicles with off-cycle technologies.**

\* \* \* \* \*

(f) \* \* \*

(2) For model years 2021 and later, you may not rely on an approval for model years before 2021. You must separately request our approval before applying an improvement factor or credit under this section for Phase 2 and Phase 3 vehicles, even if we approved an improvement factor or credit for similar vehicle models before model year 2021. Note that Phase 2 and Phase 3 approval may carry over for multiple years.

\* \* \* \* \*

80. Amend § 1037.615 by revising paragraphs (a) and (d) through (g) to read as follows:

**§ 1037.615 Advanced technologies.**

(a) This section describes how to calculate emission credits for advanced technologies. You may calculate ~~applies in~~ Phase 1 advanced technology credits through model year 2020 for hybrid vehicles with regenerative braking, vehicles equipped with Rankine-cycle engines, battery electric vehicles, and fuel cell vehicles. You may calculate, ~~and in~~ Phase 2 advanced technology credits through model year 2026~~7~~ for plug-in hybrid electric vehicles, battery electric vehicles, and fuel cell vehicles. You may calculate Phase 3 advanced technology credits for model year 2027 for fuel cell vehicles. You may not generate credits for Phase 1 engine technologies for which the engines generate credits under 40 CFR part 1036.

\* \* \* \* \*

(d) For Phase 2 and Phase 3 plug-in hybrid electric vehicles and for fuel cells powered by any fuel other than hydrogen, calculate CO<sub>2</sub> credits using an FEL based on emission measurements from powertrain testing. Phase 2 and Phase 3 advanced-~~technology~~ credits do not apply for hybrid vehicles that have no plug-in capability.

(e) ~~You may use an engineering analysis to calculate an improvement factor for fuel cell vehicles based on measured emissions from the fuel cell vehicle.~~[Reserved]

(f) For battery electric vehicles and for ~~fuel cells powered by hydrogen~~fuel cell electric vehicles, calculate CO<sub>2</sub> credits using an FEL of 0 g/ton-mile. Note that these vehicles are subject to compression-ignition standards for CO<sub>2</sub>.

(g) As specified in subpart H of this part, advanced-technology credits generated from Phase 1 vehicles under this section may be used under this part 1037 outside of the averaging set in which they were generated, or they may be used under 40 CFR part 86, subpart S, 86.1819 or 40 CFR part 1036. Advanced-technology credits generated from Phase 2 and Phase 3 vehicles are subject to all the averaging-set restrictions that apply to other emission credits.

\* \* \* \* \*

**§ 1037.620—[Amended]**

81. Amend § 1037.620 by removing paragraph (c) and redesignating paragraphs (d) through (f) as paragraphs (c) through (e).

82. Amend § 1037.622 by revising the introductory text and paragraph (d)(5) to read as follows:

**§ 1037.622 Shipment of partially complete vehicles to secondary vehicle manufacturers.**

This section specifies how manufacturers may introduce partially complete vehicles into U.S. commerce (or in the case of certain custom vehicles, introduce complete vehicles into U.S. commerce for modification by a small manufacturer). ~~The provisions of this section are generally not intended for trailers, but they may apply in unusual circumstances, such as when a secondary vehicle manufacturer will modify a trailer in a way that makes it exempt.~~The provisions of this section are intended to accommodate normal business practices without

compromising the effectiveness of certified emission controls. You may not use the provisions of this section to circumvent the intent of this part. For vehicles subject to both exhaust greenhouse gasGHG and evaporative standards, the provisions of this part apply separately for each certificate.

\* \* \* \* \*

(d) \* \* \*

(5) The provisions of this paragraph (d) may apply separately for vehicle greenhouse gasGHG, evaporative, and refueling emission standards.

\* \* \* \* \*

83. Amend § 1037.630 by revising paragraphs (a)(1)(iii) and (c) to read as follows:

**§ 1037.630 Special purpose tractors.**

(a) \* \* \*

(1) \* \* \*

(iii) Model year 2020 and earlier tractors with a gross combination weight rating (GCWR) at or above 120,000 pounds. Note that Phase 2 and Phase 3 tractors meeting the definition of “heavy-haul” in § 1037.801 must be certified to the heavy-haul standards in §§ 1037.106 or 1037.670.

\* \* \* \* \*

(c) *Production limit.* No manufacturer may produce more than 21,000 Phase 1 vehicles under this section in any consecutive three model year period. This means you may not exceed 6,000 in a given model year if the combined total for the previous two years was 15,000. The production limit applies with respect to all Class 7 and Class 8 Phase 1 tractors certified or exempted as vocational tractors. No production limit applies for tractors subject to Phase 2 and Phase 3 standards.

\* \* \* \* \*

84. Amend § 1037.631 by revising paragraph (a) introductory text to read as follows:

**§ 1037.631 Exemption for vocational vehicles intended for off-road use.**

\* \* \* \* \*

(a) *Qualifying criteria.* Vocational vehicles intended for off-road use are exempt without request, subject to the provisions of this section, if they are primarily designed to perform work off-road (such as in oil fields, mining, forests, or construction sites), and they meet at least one of the criteria of paragraph (a)(1) of this section and at least one of the criteria of paragraph (a)(2) of this section. See § 1037.105(h) for alternate Phase 2 and Phase 3 standards that apply for vehicles meeting only one of these sets of criteria.

\* \* \* \* \*

85. Amend § 1037.635 by revising paragraph (b)(1) to read as follows:

**§ 1037.635 Glider kits and glider vehicles.**

\* \* \* \* \*

(b) \* \* \*

(1) The engine must meet the greenhouse gasGHG standards of 40 CFR part 1036 that apply for the engine model year corresponding to the vehicle’s date of manufacture. For example,

for a vehicle with a 2024 date of manufacture, the engine must meet the greenhouse gasGHG standards that apply for model year 2024.

\* \* \* \* \*

86. Amend § 1037.640 by revising the introductory text to read as follows:

**§ 1037.640 Variable vehicle speed limiters.**

This section specifies provisions that apply for vehicle speed limiters (VSLs) that you model under § 1037.520. This does not apply for VSLs that you do not model under § 1037.520. (e) This section is written to apply for tractors; however, you may use good engineering judgment to apply equivalent adjustments for Phase 2 and Phase 3 vocational vehicles with vehicle speed limiters.

\* \* \* \* \*

87. Amend § 1037.660 by revising paragraphs (a)(1)(iv), (2), and (3) to read as follows:

**§ 1037.660 Idle-reduction technologies.**

\* \* \* \* \*

(a) \* \* \*

(1) \* \* \*

(iv) For Phase 2 and Phase 3 tractors, you may identify AES systems as “adjustable” if, before delivering to the ultimate purchaser, you enable authorized dealers to modify the vehicle in a way that disables the AES system or makes the threshold inactivity period longer than 300 seconds. However, the vehicle may not be delivered to the ultimate purchaser with the AES system disabled or the threshold inactivity period set longer than 300 seconds. You may allow dealers or repair facilities to make such modifications; this might involve password protection for electronic controls, or special tools that only you provide. Any dealers making any modifications before delivery to the ultimate purchaser must notify you, and you must account for such modifications in your production and ABT reports after the end of the model year. Dealers failing to provide prompt notification are in violation of the tampering prohibition of 40 CFR 1068.101(b)(1). Dealer notifications are deemed to be submissions to EPA. Note that these adjustments may not be made if the AES system was not “adjustable” when first delivered to the ultimate purchaser.

\* \* \* \* \* ~~(v) For vocational vehicles, you may use the provisions of § 1037.610 to apply for an appropriate partial emission reduction for AES systems you identify as “adjustable.”~~

(2) *Neutral idle.* Phase 2 and Phase 3 vehicles with hydrokinetic torque converters paired with automatic transmissions qualify for neutral-idle credit in GEM modeling if the transmission reduces torque equivalent to shifting into neutral throughout the interval during which the vehicle’s brake pedal is depressed and the vehicle is at a zero-speed condition (beginning within five seconds of the vehicle reaching zero speed with the brake depressed). If a vehicle reduces torque partially but not enough to be equivalent to shifting to neutral, you may use the provisions of § 1037.610(g) to apply for an appropriate partial emission reduction; this may involve A to B testing with the powertrain test procedure in 40 CFR § 1037.1036.5450 or the spin-loss portion of the transmission efficiency test in § 1037.565.

(3) *Stop-start*. Phase 2 and Phase 3 vocational vehicles qualify for stop-start reduction in GEM modeling if the engine shuts down no more than 5 seconds after the vehicle’s brake pedal is depressed when the vehicle is at a zero-speed condition.

\* \* \* \* \*

88. Amend § 1037.665 by revising paragraphs (a)(1) and (d) to read as follows:

**§ 1037.665 Production and in-use tractor testing.**

\* \* \* \* \*

(a) \* \* \*

(1) Each calendar year, select for testing three sleeper cabs and two day cabs certified to Phase 1 or Phase 2 or Phase 3 standards. If we do not identify certain vehicle configurations for your testing, select models that you project to be among your 12 highest-selling vehicle configurations for the given year.

\* \* \* \* \*

(d) Greenhouse gas**GHG** standards do not apply with respect to testing under this section. Note however that NTE standards apply for any qualifying operation that occurs during the testing in the same way that it would during any other in-use testing.

89. Amend § 1037.670 by revising paragraph (a) to read as follows:

**§ 1037.670 Optional CO<sub>2</sub> emission standards for tractors at or above 120,000 pounds GCWR.**

(a) You may certify tractors at or above 120,000 pounds GCWR to the following CO<sub>2</sub> standards instead of the Phase 2 CO<sub>2</sub> standards of § 1037.106:

TABLE 1 OF PARAGRAPH (a) OF § 1037.670—OPTIONAL PHASE 2-CO<sub>2</sub> STANDARDS FOR MODEL YEAR 2026 AND EARLIER TRACTORS ABOVE 120,000 POUNDS GCWR (g/TON-MILE)<sup>A</sup>

Subcategory	Model Years 2021 - 2023	Model Years 2024 - 2026
Heavy Class 8 Low-Roof Day Cab	53.5	50.8
Heavy Class 8 Low-Roof Sleeper Cab	47.1	44.5
Heavy Class 8 Mid-Roof Day Cab	55.6	52.8
Heavy Class 8 Mid-Roof Sleeper Cab	49.6	46.9
Heavy Class 8 High-Roof Day Cab	54.5	51.4
Heavy Class 8 High-Roof Sleeper Cab	47.1	44.2

\* \* \* \* \*

**Subpart H—Averaging, Banking, and Trading for Certification**

90. Amend § 1037.701 by revising paragraphs (a) and (h) to read as follows:

**§ 1037.701 General provisions.**

(a) You may average, bank, and trade emission credits for purposes of certification as described in this subpart and in subpart B of this part to show compliance with the standards of

§§ 1037.105 ~~through 1037.107~~ and 1037.106. Note that §§ 1037.105(h) ~~and 1037.107~~ ~~specify~~specifies standards involving limited or no use of emission credits under this subpart. Participation in this program is voluntary.

\* \* \* \* \*

(h) See § 1037.740 for special credit provisions that apply for credits generated under 40 CFR 86.1819-14-~~(k)(7)~~, 40 CFR 1036.615, or § 1037.615.

\* \* \* \* \*

91. Revise § 1037.705 to read as follows:

**§ 1037.705 Generating and calculating CO<sub>2</sub> emission credits.**

(a) The provisions of this section apply separately for calculating CO<sub>2</sub> emission credits for each pollutant.

(b) For each participating family or subfamily, calculate positive or negative emission credits relative to the otherwise applicable emission standard. Calculate positive emission credits for a family or subfamily that has an FEL below the standard. Calculate negative emission credits for a family or subfamily that has an FEL above the standard. Sum your positive and negative credits for the model year before rounding. Round the sum of emission credits to the nearest megagram (Mg), using consistent units with the following equation:

$$\text{Emission credits (Mg)} = (\text{Std} - \text{FEL}) \cdot \text{PL} \cdot \text{Volume} \cdot \text{UL} \cdot 10^{-6}$$

Where:

*Std* = the emission standard associated with the specific regulatory subcategory (g/ton-mile). For credits generated on all model year 2027 and later vocational vehicles with tailpipe CO<sub>2</sub> emissions deemed to be zero under 40 CFR 1037.150(f), use the emission standard in § 1037.105 that applies for the compression-ignition multi-purpose subcategory for the corresponding vehicle weight class.

*FEL* = the family emission limit for the vehicle subfamily (g/ton-mile).

*PL* = standard payload, in tons.

*Volume* = U.S.-directed production volume of the vehicle subfamily, subject to the exclusions described in paragraph (c) of this section. For example, if you produce three configurations with the same FEL, the subfamily production volume would be the sum of the production volumes for these three configurations.

*UL* = useful life of the vehicle, in miles, as described in §§ 1037.105 and 1037.106. ~~Use 250,000 miles for trailers.~~

(c) Compliance with the requirements of this subpart is determined at the end of the model year by calculating emission credits based on actual production volumes, excluding any of the following engines: As described in § 1037.730, compliance with the requirements of this subpart is determined at the end of the model year based on actual U.S. directed production volumes. Keep appropriate records to document these production volumes. Do not include any of the following vehicles to calculate emission credits:

(1) Vehicles that you do not certify to the CO<sub>2</sub> standards of this part because they are permanently exempted under subpart G of this part or under 40 CFR part 1068.

(2) Exported vehicles even if they are certified under this part and labeled accordingly.

(3) Vehicles not subject to the requirements of this part, such as those excluded under § 1037.5.

(4) Any other vehicles, where we indicate elsewhere in this part 1037 that they are not to be included in the calculations of this subpart.

92. Amend § 1037.710 by revising paragraph (c) to read as follows:

**§ 1037.710 Averaging.**

\* \* \* \* \*

(c) If you certify a vehicle family to an FEL that exceeds the otherwise applicable standard, you must obtain enough emission credits to offset the vehicle family's deficit by the due date for the final report required in § 1037.730. The emission credits used to address the deficit may come from your other vehicle families that generate emission credits in the same model year (or from later model years as specified in § 1037.745), from emission credits you have banked from previous model years, or from emission credits generated in the same or previous model years that you obtained through trading. ~~Note that the option for using banked or traded credits does not apply for trailers.~~

93. Amend § 1037.715 by revising paragraph (a) to read as follows:

**§ 1037.715 Banking.**

(a) Banking is the retention of surplus emission credits by the manufacturer generating the emission credits for use in future model years for averaging or trading. ~~Note that § 1037.107 does not allow banking for trailers.~~

\* \* \* \* \*

94. Amend § 1037.720 by revising paragraph (a) to read as follows:

**§ 1037.720 Trading.**

(a) Trading is the exchange of emission credits between manufacturers, or the transfer of credits to another party to retire them. You may use traded emission credits for averaging, banking, or further trading transactions. Traded emission credits remain subject to the averaging-set restrictions based on the averaging set in which they were generated. ~~Note that § 1037.107 does not allow trading for trailers.~~

\* \* \* \* \*

95. Amend § 1037.730 by revising paragraphs (b)(4) and (f) to read as follows:

**§ 1037.730 ABT reports.**

\* \* \* \* \*

(b) \* \* \*

(4) The projected and actual ~~U.S.-directed~~ production volumes for the model year for calculating emission credits. If you changed an FEL during the model year, identify the actual ~~U.S.-directed~~ production volume associated with each FEL.

\* \* \* \* \*

(f) \* \* \*

(1) If you ~~or we determine by September 30 after the end of the model year notify us by the deadline for submitting the final report~~ that errors mistakenly decreased your balance of emission credits, you may correct the errors and recalculate the balance of emission credits. If you notify us that errors mistakenly decreased your balance of emission credits after the

deadline for submitting the final report, you may correct the errors and recalculate the balance of emission credits after applying a 10 percent discount to the credit correction, but only if you notify us within 24 months after the deadline for submitting the final report. You may not make these corrections for errors that are determined later than September 30 after the end of the model year. If you report a negative balance of emission credits, we may disallow corrections under this paragraph (f)(1).

\* \* \* \* \*

96. Amend § 1037.740 by:

- a. Removing paragraphs (a)(4) and (5).
- b. Redesignating paragraph (a)(6) as paragraph (a)(4).
- c. Revising paragraphs (b)(1) introductory text and (b)(2).

The revisions read as follows:

**§ 1037.740 Restrictions for using emission credits.**

\* \* \* \* \*

(a) \* \* \*

(4) ~~Long trailers.~~

~~(5) Short trailers.~~

~~(6)~~ Note that other separate averaging sets also apply for emission credits not related to this part. For example, vehicles certified to the greenhouse gas standards of 40 CFR part 86, subpart S, 86.1819 comprise a single averaging set. Separate averaging sets also apply for engines under 40 CFR part 1036, including engines used in vehicles subject to this subpart.

(b) \* \* \*

(1) Credits generated from Phase 1 vehicles may be used for any of the averaging sets identified in paragraph (a) of this section; you may also use those credits to demonstrate compliance with the CO<sub>2</sub> emission standards in 40 CFR part 86, subpart S, 86.1819 and 40 CFR part 1036. Similarly, you may use Phase 1 advanced-technology credits generated under 40 CFR 86.1819-14(k)(7) or 40 CFR 1036.615 to demonstrate compliance with the CO<sub>2</sub> standards in this part. The maximum amount of advanced-technology credits generated from Phase 1 vehicles that you may bring into each of the following service class groups is 60,000 Mg per model year:

\* \* \* \* \*

(2) Credits generated from Phase 2 and Phase 3 vehicles are subject to all the averaging-set restrictions that apply to other emission credits.

\* \* \* \* \*

97. Amend § 1037.745 by revising paragraph (a) to read as follows:

**§ 1037.745 End-of-year CO<sub>2</sub> credit deficits.**

\* \* \* \* \*

(a) Your certificate for a vehicle family for which you do not have sufficient CO<sub>2</sub> credits will not be void if you remedy the deficit with surplus credits within three model years (this applies equally for tractors, ~~trailers~~, and vocational vehicles). For example, if you have a credit deficit of 500 Mg for a vehicle family at the end of model year 2015, you must generate (or otherwise obtain) a surplus of at least 500 Mg in that same averaging set by the end of model year 2018.



\* \* \* \* \*

## Subpart I—Definitions and Other Reference Information

98. Amend § 1037.801 by:

- a. Adding a definition of “Battery electric vehicle” in alphabetical order.
- b. Removing the definition of “Box van”.
- c. Revising the definition of “Class”.
- d. Removing the definitions of “Container chassis”, “Electric vehicle”, and “Flatbed trailer”.
- e. Adding a definition of “Fuel cell electric vehicle” in alphabetical order.
- f. Revising the definitions of “Heavy-duty vehicle” and “Heavy-haul tractor”.
- g. Adding a definition of “Hybrid” in alphabetical order.
- h. Removing the definitions of “Hybrid engine or hybrid powertrain” and “Hybrid vehicle”.
- i. Revising the definitions of “Low rolling resistance tire”, “Manufacturer”, and “Model year”.
- j. Adding a definition of “Neat” in alphabetical order.
- k. Revising the definitions of “Phase 1” and “Phase 2”.
- l. Adding definitions of “Phase 3” and “Plug-in hybrid electric vehicle” in alphabetical order.
- m. Revising the definitions of “Preliminary approval”, “Small manufacturer”, and “Standard payload”.
- n. Removing the definitions of “Standard tractor” and “Tank trailer”.
- o. Revising the definitions of “Tire rolling resistance level (TRRL)”, “Trailer”, “U.S.-directed production volume”, and “Vehicle”.

The additions and revision read as follows:

### § 1037.801 Definitions.

\* \* \* \* \*

*Battery electric vehicle means a motor vehicle powered solely by an electric motor where energy for the motor is supplied by one or more batteries that receive power from an external source of electricity. Note that this definition does not include hybrid vehicles or plug-in hybrid electric vehicles.*

~~*Box van has the meaning given in the definition for “trailer” in this section.*~~

\* \* \* \* \*

*Class* means relating to GVWR classes for vehicles ~~other than trailers~~, as follows:

- (1) *Class 2b* means relating to heavy-duty motor vehicles at or below 10,000 pounds GVWR.
- (2) *Class 3* means relating to heavy-duty motor vehicles above 10,000 pounds GVWR but at or below 14,000 pounds GVWR.
- (3) *Class 4* means relating to heavy-duty motor vehicles above 14,000 pounds GVWR but at or below 16,000 pounds GVWR.
- (4) *Class 5* means relating to heavy-duty motor vehicles above 16,000 pounds GVWR but at or below 19,500 pounds GVWR.
- (5) *Class 6* means relating to heavy-duty motor vehicles above 19,500 pounds GVWR but at or below 26,000 pounds GVWR.
- (6) *Class 7* means relating to heavy-duty motor vehicles above 26,000 pounds GVWR but at or below 33,000 pounds GVWR.
- (7) *Class 8* means relating to heavy-duty motor vehicles above 33,000 pounds GVWR.

\* \* \* \* \*

~~*Container chassis* means a trailer designed for carrying temporarily mounted shipping containers.~~

~~*Electric vehicle* means a motor vehicle that does not include an engine, and is powered solely by an external source of electricity and/or solar power. Note that this definition does not include hybrid electric vehicles or fuel cell vehicles that use a chemical fuel such as gasoline, diesel fuel, or hydrogen. Electric vehicles may also be referred to as all electric vehicles to distinguish them from hybrid vehicles.~~

~~*Flatbed trailer* means a trailer designed to accommodate side loading cargo onto a single, continuous load-bearing surface that runs from the rear of the trailer to at least the trailer's kingpin. This includes trailers that use curtains, straps, or other devices to restrain or protect cargo while underway. It also may include similar trailers that have one or more side walls without completely enclosing the cargo space. For purposes of this definition, disregard any ramps, moveable platforms, or other rear-mounted equipment or devices designed to assist with loading the trailer.~~

\* \* \* \* \*

*Fuel cell electric vehicle* means a motor vehicle powered solely by an electric motor where energy for the motor is supplied by hydrogen fuel cells. Fuel cell electric vehicles may include energy storage from the fuel cells or from regenerative braking in a battery.

\* \* \* \* \*

*Heavy-duty vehicle* means any ~~trailer and any other~~ motor vehicle that has a GVWR above 8,500 pounds. An incomplete vehicle is also a heavy-duty vehicle if it has a curb weight above 6,000 pounds or a basic vehicle frontal area greater than 45 square feet.

*Heavy-haul tractor* means a tractor with GCWR greater than or equal to 120,000 pounds. A heavy-haul tractor is not a vocational tractor in Phase 2 and Phase 3.

\* \* \* \* \*

*Hybrid* has the meaning given in 40 CFR 1036.801. Note that a hybrid vehicle is a vehicle with a hybrid powertrain (including a hybrid engine). This includes plug-in hybrid electric vehicles.

~~*Hybrid engine or hybrid powertrain* means an engine or powertrain that includes energy storage features other than a conventional battery system or conventional flywheel. Supplemental electrical batteries and hydraulic accumulators are examples of hybrid energy storage systems. Note other examples of systems that qualify as hybrid engines or powertrains are systems that recover kinetic energy and use it to power an electric heater in the aftertreatment. Note that certain provisions in this part treat hybrid engines and hybrid powertrains intended for vehicles that include regenerative braking different than those intended for vehicles that do not include regenerative braking.~~

~~*Hybrid vehicle* means a vehicle that includes energy storage features (other than a conventional battery system or conventional flywheel) in addition to an internal combustion engine or other engine using consumable chemical fuel. Supplemental electrical batteries and hydraulic~~

~~accumulators are examples of hybrid energy storage systems. Note other examples of systems that qualify as hybrid engines or powertrains are systems that recover kinetic energy and use it to power an electric heater in the aftertreatment. Note that certain provisions in this part treat hybrid vehicles that include regenerative braking different than those that do not include regenerative braking.~~

\* \* \* \* \*

*Low rolling resistance tire* means a tire on a vocational vehicle with a TRRL at or below of 7.7 N/kN, a steer tire on a tractor with a TRRL at or below 7.7 N/kN, a drive tire on a tractor with a TRRL at or below 8.1 N/kN, ~~a tire on a non-box trailer with a TRRL at or below of 6.5 N/kN, or a tire on a box van with a TRRL at or below of 6.0 N/kN.~~

\* \* \* \* \*

*Manufacturer* has the meaning given in section 216(1) of the Act. In general, this term includes any person who manufactures or assembles a vehicle (including ~~a trailer or another an~~ incomplete vehicle) for sale in the United States or otherwise introduces a new motor vehicle into commerce in the United States. This includes importers who import vehicles for resale, entities that manufacture glider kits, and entities that assemble glider vehicles.

\* \* \* \* \*

*Model year* means one of the following for compliance with this part. Note that manufacturers may have other model year designations for the same vehicle for compliance with other requirements or for other purposes:

(1) For tractors and vocational vehicles with a date of manufacture on or after January 1, 2021, *model year* means the manufacturer's annual new model production period based on the vehicle's date of manufacture, where the model year is the calendar year corresponding to the date of manufacture, except as follows:

(i) The vehicle's model year may be designated as the year before the calendar year corresponding to the date of manufacture if the engine's model year is also from an earlier year. You may ask us to extend your prior model year certificate to include such vehicles. Note that § 1037.601(a)(2) limits the extent to which vehicle manufacturers may install engines built in earlier calendar years.

(ii) The vehicle's model year may be designated as the year after the calendar year corresponding to the vehicle's date of manufacture. For example, a manufacturer may produce a new vehicle by installing the engine in December 2023 and designating it as a model year 2024 vehicle.

(2) For ~~trailers and for~~ Phase 1 tractors and vocational vehicles with a date of manufacture before January 1, 2021, *model year* means the manufacturer's annual new model production period, except as restricted under this definition and 40 CFR part 85, subpart X. It must include January 1 of the calendar year for which the model year is named, may not begin before January 2 of the previous calendar year, and it must end by December 31 of the named calendar year. The model year may be set to match the calendar year corresponding to the date of manufacture.

(i) The manufacturer who holds the certificate of conformity for the vehicle must assign the model year based on the date when its manufacturing operations are completed relative to its annual model year period. In unusual circumstances where completion of

your assembly is delayed, we may allow you to assign a model year one year earlier, provided it does not affect which regulatory requirements will apply.

(ii) Unless a vehicle is being shipped to a secondary vehicle manufacturer that will hold the certificate of conformity, the model year must be assigned prior to introduction of the vehicle into U.S. commerce. The certifying manufacturer must redesignate the model year if it does not complete its manufacturing operations within the originally identified model year. A vehicle introduced into U.S. commerce without a model year is deemed to have a model year equal to the calendar year of its introduction into U.S. commerce unless the certifying manufacturer assigns a later date.

\* \* \* \* \*

Neat has the meaning given in 40 CFR 1065.1001.

\* \* \* \* \*

*Phase 1* means relating to the Phase 1 standards specified in §§ 1037.105 and 1037.106. For example, a vehicle subject to the Phase 1 standards is a Phase 1 vehicle. ~~Note that there are no Phase 1 standards for trailers.~~

*Phase 2* means relating to the Phase 2 standards specified in §§ 1037.105 ~~through 1037.107~~ and 1037.106.

*Phase 3* means relating to the Phase 3 standards specified in §§ 1037.105 and 1037.106.

\* \* \* \* \*

*Plug-in hybrid electric vehicle* means a hybrid vehicle that has the capability to charge one or more batteries from an external source of electricity while the vehicle is parked.

\* \* \* \* \*

*Preliminary approval* means approval granted by an authorized EPA representative prior to submission of an application for certification, consistent with the provisions of § 1037.210 ~~or 1037.211~~.

\* \* \* \* \*

*Small manufacturer* means a manufacturer meeting the small business criteria specified in 13 CFR 121.201 for heavy-duty truck manufacturing ~~vocational vehicles and tractors~~ (NAICS code 336120) ~~or for trailers (NAICS code 336212)~~. ~~Apply the small business criteria for NAICS code 336120 for vocational vehicles and tractors and 336212 for trailers.~~ The employee ~~and revenue~~ limits apply to the total number employees ~~and total revenue together~~ for all affiliated companies (as defined in 40 CFR 1068.30).

\* \* \* \* \*

*Standard payload* means the payload assumed for each vehicle, in tons, for modeling and calculating emission credits, as follows:

- (1) For vocational vehicles:
  - (i) 2.85 tons for Light HDV.
  - (ii) 5.6 tons for Medium HDV.
  - (iii) 7.5 tons for Heavy HDV.
- (2) For tractors:

- (i) 12.5 tons for Class 7.
- (ii) 19 tons for Class 8, other than heavy-haul tractors.
- (iii) 43 tons for heavy-haul tractors.

~~(3) For trailers:~~

- ~~(i) 10 tons for short box vans.~~
- ~~(ii) 19 tons for other trailers.~~

~~Standard tractor has the meaning given in § 1037.501.~~

\* \* \* \* \*

~~Tank trailer means a trailer designed to transport liquids or gases.~~

*Tire rolling resistance level (TRRL)* means a value with units of N/kN that represents the rolling resistance of a tire configuration. TRRLs are used as modeling inputs under §§ ~~1037.515 and~~ 1037.520. Note that a manufacturer may use the measured value for a tire configuration's coefficient of rolling resistance, or assign some higher value.

\* \* \* \* \*

*Trailer* means a piece of equipment designed for carrying cargo and for being drawn by a tractor when coupled to the tractor's fifth wheel. ~~These trailers may be known commercially as semi-trailers or truck trailers. This definition excludes equipment that serve similar purposes but are not intended to be pulled by a tractor, whether or not they are known commercially as trailers. Trailers may be divided into different types and categories as described in paragraphs (1) through (4) of this definition. The types of equipment identified in paragraph (5) of this definition are not trailers for purposes of this part.~~

~~(1) Box vans are trailers with enclosed cargo space that is permanently attached to the chassis, with fixed sides, nose, and roof. Tank trailers are not box vans.~~

~~(2) Box vans with self-contained HVAC systems are refrigerated vans. Note that this includes systems that provide cooling, heating, or both. All other box vans are dry vans.~~

~~(3) Trailers that are not box vans are non-box trailers. Note that the standards for non-box trailers in this part 1037 apply only to flatbed trailers, tank trailers, and container chassis.~~

~~(4) Box vans with length at or below 50.0 feet are short box vans. Other box vans are long box vans.~~

~~(5) The following types of equipment are not trailers for purposes of this part 1037:~~

~~(i) Containers that are not permanently mounted on chassis.~~

~~(ii) Dollies used to connect tandem trailers.~~

\* \* \* \* \*

*U.S.-directed production volume* means the number of vehicle units, subject to the requirements of this part, produced by a manufacturer for which the manufacturer has a reasonable assurance that sale was or will be made to ultimate purchasers in the United States. Note that this includes ~~This does not include~~ vehicles certified to state emission standards that are different than the

emission standards in this part.

\* \* \* \* \*

*Vehicle* means equipment intended for use on highways that meets at least one of the criteria of paragraph (1) of this definition, as follows:

(1) The following equipment are vehicles:

(i) A piece of equipment that is intended for self-propelled use on highways becomes a vehicle when it includes at least an engine, a transmission, and a frame. (Note: For purposes of this definition, any electrical, mechanical, and/or hydraulic devices attached to engines for the purpose of powering wheels are considered to be transmissions.)

(ii) A piece of equipment that is intended for self-propelled use on highways becomes a vehicle when it includes a passenger compartment attached to a frame with one or more axles.

~~(iii) Trailers. A trailer becomes a vehicle when it has a frame with one or more axles attached.~~

(2) Vehicles ~~other than trailers~~ may be complete or incomplete vehicles as follows:

(i) A *complete vehicle* is a functioning vehicle that has the primary load carrying device or container (or equivalent equipment) attached when it is first sold as a vehicle. Examples of equivalent equipment would include fifth wheel trailer hitches, firefighting equipment, and utility booms.

(ii) An *incomplete vehicle* is a vehicle that is not a complete vehicle. Incomplete vehicles may also be cab-complete vehicles. This may include vehicles sold to secondary vehicle manufacturers.

~~(iii) The primary use of the terms “complete vehicle” and “incomplete vehicle” are to distinguish whether a vehicle is complete when it is first sold as a vehicle.~~

~~(iv)~~ You may ask us to allow you to certify a vehicle as incomplete if you manufacture the engines and sell the unassembled chassis components, as long as you do not produce and sell the body components necessary to complete the vehicle.

\* \* \* \* \*

99. Amend § 1037.805 by revising Table 5 in paragraph (e) with an added entry for “GHG” in alphabetical order and removing the entry for “PHEV” to read as follows:

**§ 1037.805 Symbols, abbreviations, and acronyms.**

\* \* \* \* \*

(e) \* \* \*

TABLE 5 TO PARAGRAPH (e) OF § 1037.805—OTHER ACRONYMS AND ABBREVIATIONS

ACRONYM	MEANING
	* * * * *
GHG	Greenhouse gas.
	* * * * *

\* \* \* \* \*

100. Amend § 1037.810 by;

a. Removing paragraph (c)(9).

b. Redesignating paragraph (c)(10) as paragraph (c)(9).

- c. Revising paragraph (d)(4).
- d. Adding paragraph (e).

The revision and addition read as follows:

**§ 1037.810 Incorporation by reference.**

\* \* \* \* \*

(d) \* \* \*

(4) Greenhouse gas Emissions Model (GEM) Phase 2, Version 4.0, April 2022 (“GEM Phase 2, Version 4.0”); IBR approved for §§ 1037.150(bb); 1037.520; ~~1037.550(a)~~.

\* \* \* \* \*

(e) UN Economic Commission for Europe, Information Service, Palais des Nations, CH-1211 Geneva 10, Switzerland; [unece\\_info@un.org](mailto:unece_info@un.org); [www.unece.org](http://www.unece.org):

(1) Addendum 22: United Nations Global Technical Regulation, No. 22, United Nations Global Technical Regulation on In-vehicle Battery Durability for Electrified Vehicles, Adopted April 14, 2022, (“GTR No. 22”); IBR approved for § 1037.115(f).

(2) [Reserved]

101. Revise appendix C of part 1037 to read as follows:

**Appendix C of Part 1037 — Emission Control Identifiers**

This appendix identifies abbreviations for emission control information labels, as required under § 1037.135.

**Vehicle Speed Limiters**

- VSL – Vehicle speed limiter
- VSLs – “Soft-top” vehicle speed limiter
- VSLE – Expiring vehicle speed limiter
- VSLD – Vehicle speed limiter with both “soft-top” and expiration

**Idle Reduction Technology**

- IRT5 – Engine shutoff after 5 minutes or less of idling
- IRTE – Expiring engine shutoff

**Tires**

- LRRa – Low rolling resistance tires (all, ~~including trailers~~)
- LRRD – Low rolling resistance tires (drive)
- LRRS – Low rolling resistance tires (steer)

**Aerodynamic Components**

- ATS – Aerodynamic side skirt and/or fuel tank fairing
- ARF – Aerodynamic roof fairing
- ARFR – Adjustable height aerodynamic roof fairing
- TGR – Gap reducing tractor fairing (tractor to trailer gap)
- ~~-TGRT – Gap reducing trailer fairing (tractor to trailer gap)~~
- ~~-TATS – Trailer aerodynamic side skirt~~
- ~~-TARF – Trailer aerodynamic rear fairing~~
- ~~-TAUD – Trailer aerodynamic underbody device~~

Other Components

- ADVH – Vehicle includes advanced hybrid technology components
- ADVO – Vehicle includes other advanced-technology components (i.e., non-hybrid system)
- INV – Vehicle includes innovative (off-cycle) technology components
- ATI – Automatic tire inflation system
- TPMS – Tire pressure monitoring system

- ~~-WRTW – Weight reducing trailer wheels~~
- ~~-WRTC – Weight reducing trailer upper coupler plate~~
- ~~-WRTS – Weight reducing trailer axle sub-frames~~
- ~~-WBSW – Wide base single trailer tires with steel wheel~~
- ~~-WBAW – Wide base single trailer tires with aluminum wheel~~
- ~~-WBLW – Wide base single trailer tires with light weight aluminum alloy wheel~~
- ~~-DWSW – Dual wide trailer tires with high strength steel wheel~~
- ~~-DWAW – Dual wide trailer tires with aluminum wheel~~
- ~~-DWLW – Dual wide trailer tires with light weight aluminum alloy wheel~~

102. Amend appendix D of part 1037 by revising the appendix heading to read as follows:  
**Appendix D of Part 1037 — Heavy-duty Grade Profile for Phase 2 and Phase 3 Steady-State Test Cycles**

\* \* \* \* \*

**PART 1054— CONTROL OF EMISSIONS FROM NEW, SMALL NONROAD SPARK-IGNITION ENGINES AND EQUIPMENT**

103. The authority citation for part 1054 continues to read as follows:  
 Authority: 42 U.S.C. 7401-7671q.

104. Amend § 1054.501 by revising paragraph (b)(7) to read as follows:

**§ 1054.501 How do I run a valid emission test?**

\* \* \* \* \*

(b) \* \* \*

(7) Determine your test fuel's ~~the~~ carbon mass fraction ~~of fuel~~,  $w_c$ , using a calculation based on ~~measured~~ fuel properties as described in 40 CFR 1065.655(d)(1); however, you must measure fuel properties for  $\alpha$  and  $\beta$  rather than using the default values specified in ~~You may not use the default values specified in~~ 40 CFR 1065.655(e)(d)(2).

\* \* \* \* \*

**PART 1065—ENGINE-TESTING PROCEDURES**

105. The authority citation for part 1065 continues to read as follows:  
 Authority: 42 U.S.C. 7401-7671q.

**Subpart C—Measurement Instruments**



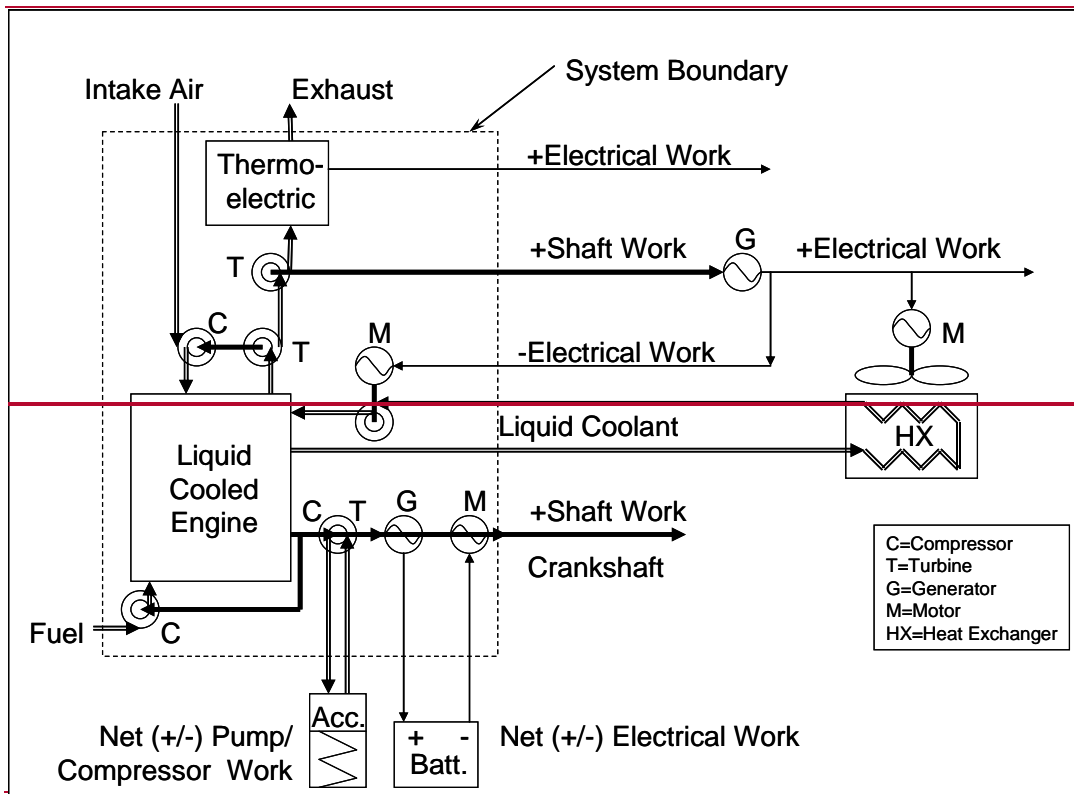
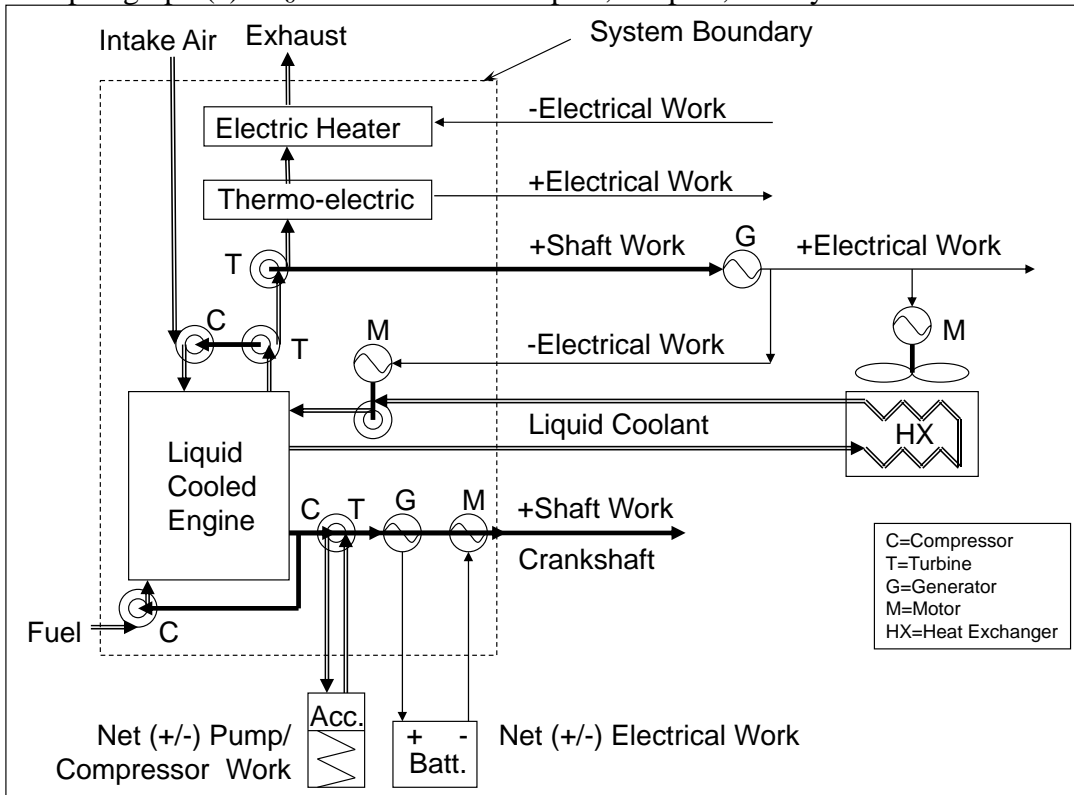
## MEASUREMENT OF ENGINE PARAMETERS AND AMBIENT CONDITIONS

106. Amend § 1065.210 by revising paragraph (a) to read as follows:

### **§ 1065.210 Work input and output sensors.**

(a) *Application.* Use instruments as specified in this section to measure work inputs and outputs during engine operation. We recommend that you use sensors, transducers, and meters that meet the specifications in Table 1 of § 1065.205. Note that your overall systems for measuring work inputs and outputs must meet the linearity verifications in § 1065.307. We recommend that you measure work inputs and outputs where they cross the system boundary as shown in Figure 1 of this section. The system boundary is different for air-cooled engines than for liquid-cooled engines. If you choose to measure work before or after a work conversion, relative to the system boundary, use good engineering judgment to estimate any work-conversion losses in a way that avoids overestimation of total work. For example, if it is impractical to instrument the shaft of an exhaust turbine generating electrical work, you may decide to measure its converted electrical work. As another example, your engine may include an engine exhaust electrical heater where the heater is powered by an external power source. In these cases, assume an electrical generator efficiency of 0.867 ( $\eta = 0.678$ ), which is a conservative estimate of the efficiency and could overestimate brake-specific emissions. As another example, you may decide to measure the tractive (i.e., electrical output) power of a locomotive, rather than the brake power of the locomotive engine. In these cases, divide the electrical work by accurate values of electrical generator efficiency ( $\eta < 1$ ), or assume an efficiency of 1 ( $\eta = 1$ ), which would over-estimate brake-specific emissions. For the example of using locomotive tractive power with a generator efficiency of 1 ( $\eta = 1$ ), this means using the tractive power as the brake power in emission calculations. Do not underestimate any work conversion efficiencies for any components outside the system boundary that do not return work into the system boundary. And do not overestimate any work conversion efficiencies for components outside the system boundary that do return work into the system boundary. In all cases, ensure that you are able to accurately demonstrate compliance with the applicable standards in this chapter. Figure 1 follows:

Figure 1 to paragraph (a) of § 1065.210: Work Inputs, Outputs, and System Boundaries





\* \* \* \* \*

107. Amend subpart C by adding a new center header “H<sub>2</sub> AND H<sub>2</sub>O MEASUREMENTS” after § 1065.250 and adding §§ 1065.255 and 1065.257 under the new center header to read as follows:

### H<sub>2</sub> AND H<sub>2</sub>O MEASUREMENTS

#### § 1065.255 H<sub>2</sub> measurement devices.

(a) General component requirements. We recommend that you use an analyzer that meets the specifications in Table 1 of § 1065.205. Note that your system must meet the linearity verification in § 1065.307.

(b) Instrument types. You may use any of the following analyzers to measure H<sub>2</sub>:

(1) Magnetic sector mass spectrometer.

(2) Raman spectrometer.

(c) Interference verification. Certain species can positively interfere with magnetic sector mass spectroscopy and raman spectroscopy by causing a response similar to H<sub>2</sub>. When running the interference verification for these analyzers, use good engineering judgment to determine interference species. Note that for raman spectroscopy interference species are dependent on the H<sub>2</sub> infrared absorption band chosen by the instrument manufacturer. For each analyzer determine the H<sub>2</sub> infrared absorption band. For each H<sub>2</sub> infrared adsorption band, determine the interference species to use in the verification. Use the interference species specified by the instrument manufacturer or use good engineering judgment to determine the interference species.

#### § 1065.257 Fourier transform infrared analyzer for H<sub>2</sub>O measurement.

(a) Component requirements. We recommend that you use an FTIR analyzer that meets the specifications in Table 1 of § 1065.205. Note that your system must meet the linearity verification in § 1065.307 using a water generation system that meets the requirements of § 1065.750(a)(6). Use appropriate analytical procedures for interpretation of infrared spectra. For example, EPA Test Method 320 (see § 1065.266(b)) and ASTM D6348 (incorporated by reference in § 1065.1010) are considered valid methods for spectral interpretation. You must use heated FTIR analyzers that maintain all surfaces that are exposed to emissions at a temperature of (110 to 202) °C.

(b) Interference verification. Certain species can interfere with FTIR analyzers by causing a response similar to the water.

(1) Perform CO<sub>2</sub> interference verification for FTIR analyzers using the procedures of § 1065.357 as CO<sub>2</sub> gas can positively interfere with FTIR analyzers by causing a response similar to H<sub>2</sub>O.

(2) Use good engineering judgment to determine other interference species for FTIR analyzers. Possible interference species include, but are not limited to, CO, NO, C<sub>2</sub>H<sub>4</sub>, and C<sub>7</sub>H<sub>8</sub>. Perform interference verification using the procedures of § 1065.357, replacing occurrences of CO<sub>2</sub> (except for § 1065.357(e)(1)) with the targeted interferent specie. Note that interference species, with the exception of CO<sub>2</sub>, are dependent on the H<sub>2</sub>O infrared absorption band chosen by the instrument manufacturer. For each analyzer determine the H<sub>2</sub>O infrared absorption band. For each H<sub>2</sub>O infrared absorption band, use good engineering judgment to determine interference species to use in the verification.

### HYDROCARBON MEASUREMENTS

108. Amend § 1065.266 by revising paragraph (e) as follows:

**§ 1065.266 Fourier transform infrared analyzer.**

\* \* \* \* \*

(e) *Interference verification.* Perform interference verification for FTIR analyzers using the procedures of § 1065.366. Certain ~~interference-gases-species~~ can interfere with FTIR analyzers by causing a response similar to the hydrocarbon species of interest. When running the interference verification for these analyzers, use interference ~~gases-species~~ as follows:

- (1) The interference ~~gases-species~~ for CH<sub>4</sub> are CO<sub>2</sub>, H<sub>2</sub>O, and C<sub>2</sub>H<sub>6</sub>.
- (2) The interference ~~gases-species~~ for C<sub>2</sub>H<sub>6</sub> are CO<sub>2</sub>, H<sub>2</sub>O, and CH<sub>4</sub>.
- (3) The interference ~~gases-species~~ for other measured hydrocarbon species are CO<sub>2</sub>, H<sub>2</sub>O, CH<sub>4</sub>, and C<sub>2</sub>H<sub>6</sub>.

109. Revise the undesignated center heading preceding § 1065.270 to read as follows:

NO<sub>x</sub>, ~~AND~~ N<sub>2</sub>O, ~~AND~~ NH<sub>3</sub> MEASUREMENTS

110. Add § 1065.277 under the undesignated and newly revised center header “NO<sub>x</sub>, N<sub>2</sub>O, and NH<sub>3</sub> Measurements” to read as follows:

**§ 1065.277 NH<sub>3</sub> measurement devices.**

(a) General component requirements. We recommend that you use an analyzer that meets the specifications in Table 1 of § 1065.205. Note that your system must meet the linearity verification in § 1065.307.

(b) Instrument types. You may use any of the following analyzers to measure NH<sub>3</sub>:

- (1) Nondispersive ultraviolet (NDUV) analyzer.
- (2) Fourier transform infrared (FTIR) analyzer. Use appropriate analytical procedures for interpretation of infrared spectra. For example, EPA Test Method 320 (see § 1065.266(b)) and ASTM D6348 (incorporated by reference in § 1065.1010) are considered valid methods for spectral interpretation.
- (3) Laser infrared analyzer. Examples of laser infrared analyzers are pulsed-mode high-resolution narrow band mid-infrared analyzers, modulated continuous wave high-resolution narrow band mid-infrared analyzers, and modulated continuous wave high-resolution near-infrared analyzers. A quantum cascade laser, for example, can emit coherent light in the mid-infrared region where nitrogen compounds including NH<sub>3</sub> have strong absorption.

(c) Sampling system. NH<sub>3</sub> has a tendency to adsorb to surfaces that it encounters. Minimize NH<sub>3</sub> losses and sampling artifacts by using sampling system components (sample lines, prefilters and valves) made of stainless steel or PTFE heated to (110 to 202) °C. If you heat these components to temperatures ≥130 °C, use good engineering judgement to minimize NH<sub>3</sub> formation due to thermal decomposition and hydrolysis of any DEF present in the sample gas. Use a sample line that is as short as practically possible.

(d) Interference verification. Certain species can positively interfere with NDUV, FTIR, and laser infrared analyzers by causing a response similar to NH<sub>3</sub>. Perform interference verification for NDUV analyzers using the procedures of § 1065.372, replacing occurrences of NO<sub>x</sub> with NH<sub>3</sub> and interference species with those listed in paragraph (d)(1) of this section. NDUV analyzers must have combined interference that is within (0.0 ±2.0) µmol/mol. Perform interference verification for FTIR and laser infrared analyzers using the procedures of § 1065.377. When running the interference verification for these analyzers, use interference species as follows:

- (1) For NDUV analyzers, use SO<sub>2</sub> and H<sub>2</sub>O as the interference species.
- (2) Use good engineering judgment to determine interference species for FTIR and laser infrared analyzers. Note that interference species, with the exception of H<sub>2</sub>O, are dependent on the NH<sub>3</sub> infrared absorption band chosen by the instrument manufacturer. For each analyzer determine the NH<sub>3</sub> infrared absorption band. For each NH<sub>3</sub> infrared absorption band, use the interference gases specified by the instrument manufacturer or use good engineering judgment to determine the interference gases to use in the verification.

**Subpart D—Calibrations and Verifications**

111. Amend § 1065.315 by revising paragraphs (a)(2) and (3) to read as follows:

**§ 1065.315 Pressure, temperature, and dewpoint calibration.**

(a) \* \* \*

(2) *Temperature.* We recommend digital dry-block or stirred-liquid temperature calibrators, with data logging capabilities to minimize transcription errors. We recommend using calibration reference quantities that are NIST-traceable within ±0.5 % uncertainty of absolute temperature. You may perform linearity verification for temperature measurement systems with thermocouples, RTDs, and thermistors by removing the sensor from the system and using a simulator in its place. Use a NIST-traceable simulator that is independently calibrated and, as appropriate, cold-junction compensated. The simulator uncertainty scaled to absolute temperature must be less than 0.5 % of  $T_{max}$ . If you use this option, you must use sensors that the supplier states are accurate to better than 0.5 % of  $T_{max}$  compared with their standard calibration curve.

(3) *Dewpoint.* We recommend a minimum of three different temperature-equilibrated and temperature-monitored calibration salt solutions in containers that seal completely around the dewpoint sensor. We recommend using calibration reference quantities that are NIST-traceable within ±0.5 % uncertainty of absolute dewpoint temperature.

\* \* \* \* \*

112. Amend subpart D by adding a new center header “H<sub>2</sub>O MEASUREMENTS” after § 1065.355 and adding §§ 1065.357 under the new center header to read as follows:

**H<sub>2</sub>O MEASUREMENTS**

**§ 1065.357 CO<sub>2</sub> interference verification for H<sub>2</sub>O FTIR analyzers.**

(a) Scope and frequency. If you measure H<sub>2</sub>O using an FTIR analyzer, verify the amount of CO<sub>2</sub> interference after initial analyzer installation and after major maintenance.

(b) Measurement principles. CO<sub>2</sub> can interfere with an FTIR analyzer’s response to H<sub>2</sub>O. If the FTIR analyzer uses compensation algorithms that utilize measurements of other gases to meet this interference verification, simultaneously conduct these other measurements to test the compensation algorithms during the analyzer interference verification.

(c) System requirements. An H<sub>2</sub>O FTIR analyzer must have a CO<sub>2</sub> interference that is within (0.0 ±0.4) mmol/mol, though we strongly recommend a lower interference that is within (0.0 ±0.2) mmol/mol.

(d) Procedure. Perform the interference verification as follows:

(1) Start, operate, zero, and span the H<sub>2</sub>O FTIR analyzer as you would before an emission test.

(2) Use a CO<sub>2</sub> span gas that meets the specifications of § 1065.750 and a concentration that is approximately the maximum CO<sub>2</sub> concentration expected during emission testing.

- (3) Introduce the CO<sub>2</sub> test gas into the sample system.
- (4) Allow time for the analyzer response to stabilize. Stabilization time may include time to purge the transfer line and to account for analyzer response.
- (5) While the analyzer measures the sample's concentration, record 30 seconds of sampled data. Calculate the arithmetic mean of this data. The analyzer meets the interference verification if this value is within (0.0 ±0.4) mmol/mol.

(e) Exceptions. The following exceptions apply:

- (1) You may omit this verification for CO<sub>2</sub> for engines operating on fuels other than carbon-containing fuels.
- (2) You may omit this verification if you can show by engineering analysis that for your H<sub>2</sub>O sampling system and your emission-calculation procedures, the CO<sub>2</sub> interference for your H<sub>2</sub>O FTIR analyzer always affects your brake-specific emission results within ±0.5 % of each of the applicable standards in this chapter. This specification also applies for vehicle testing, except that it relates to emission results in g/mile or g/kilometer.
- (3) You may use an H<sub>2</sub>O FTIR analyzer that you determine does not meet this verification, as long as you try to correct the problem and the measurement deficiency does not adversely affect your ability to show that engines comply with all applicable emission standards.

## HYDROCARBON MEASUREMENTS

113. Amend § 1065.360 by revising paragraphs (a)(4), (b), (d) introductory text, and (d)(12) to read as follows:

### § 1065.360 FID optimization and verification.

(a) \* \* \*

~~(4) For any gaseous fueled engine, including dual-fuel and flexible-fuel engines, y~~ You may determine the methane (CH<sub>4</sub>) and ethane (C<sub>2</sub>H<sub>6</sub>) response factors as a function of the molar water concentration in the raw or diluted exhaust. If you choose the option in this paragraph (a)(4), generate and verify the humidity level (or fraction) as described in § 1065.365~~(dg)(11)~~.

(b) *Calibration.* Use good engineering judgment to develop a calibration procedure, such as one based on the FID-analyzer manufacturer's instructions and recommended frequency for calibrating the FID. Alternately, you may remove system components for off-site calibration. For a FID that measures THC, calibrate using C<sub>3</sub>H<sub>8</sub> calibration gases that meet the specifications of § 1065.750. For a FID that measures CH<sub>4</sub>, calibrate using CH<sub>4</sub> calibration gases that meet the specifications of § 1065.750. We recommend FID analyzer zero and span gases that contain approximately the flow-weighted mean concentration of O<sub>2</sub> expected during testing. If you use a FID to measure CH<sub>4</sub> downstream of a nonmethane cutter (NMC), you may calibrate that FID using CH<sub>4</sub> calibration gases with the ~~cutter~~NMC. Regardless of the calibration gas composition, calibrate on a carbon number basis of one (C<sub>1</sub>). For example, if you use a C<sub>3</sub>H<sub>8</sub> span gas of concentration 200 µmol/mol, span the FID to respond with a value of 600 µmol/mol. As another example, if you use a CH<sub>4</sub> span gas with a concentration of 200 µmol/mol, span the FID to respond with a value of 200 µmol/mol.

\* \* \* \* \*

(d) *THC FID CH<sub>4</sub> response factor determination.* This procedure is only for FID analyzers that measure THC. Since FID analyzers generally have a different response to CH<sub>4</sub> versus C<sub>3</sub>H<sub>8</sub>, determine the THC-FID analyzer's CH<sub>4</sub> response factor,  $RF_{CH_4[THC-FID]}$ , after FID optimization. Use the most recent  $RF_{CH_4[THC-FID]}$  measured according to this section in the calculations for HC

determination described in § 1065.660 to compensate for CH<sub>4</sub> response. Determine  $RF_{CH_4[THC-FID]}$  as follows, noting that you do not determine  $RF_{CH_4[THC-FID]}$  for FIDs that are calibrated and spanned using CH<sub>4</sub> with a ~~n NMC nonmethane cutter~~:

\* \* \* \* \*

(12) ~~You may determine~~ the response factor as a function of molar water concentration and use this response factor to account for the CH<sub>4</sub> response for NMHC determination described in § 1065.660(b)(2)(iii). ~~If you use this option, humidify~~ the CH<sub>4</sub> span gas as described in § 1065.365(dg)(11) and repeat the steps in paragraphs (d)(7) through (9) of this section until measurements are complete for each setpoint in the selected range. Divide each mean measured CH<sub>4</sub> concentration by the recorded span concentration of the CH<sub>4</sub> calibration gas, adjusted for water content, to determine the FID analyzer's CH<sub>4</sub> response factor,  $RF_{CH_4[THC-FID]}$ . Use the CH<sub>4</sub> response factors at the different setpoints to create a functional relationship between response factor and molar water concentration, downstream of the last sample dryer if any sample dryers are present. Use this functional relationship to determine the response factor during an emission test.

\* \* \* \* \*

114. Revise § 1065.365 to read as follows:

**§ 1065.365 Nonmethane cutter penetration fractions and NMC FID response factors.**

(a) *Scope and frequency.* If you use a FID analyzer and a nonmethane cutter (NMC) to measure methane (CH<sub>4</sub>), determine the ~~nonmethane cutter~~NMC's penetration fractions of ~~methane~~CH<sub>4</sub>,  $PF_{CH_4}$ , and ethane (C<sub>2</sub>H<sub>6</sub>),  $PF_{C_2H_6}$ . As detailed in this section, these penetration fractions may be determined as a combination of NMC penetration fractions and FID analyzer response factors, depending on your particular NMC and FID analyzer configuration. Perform this verification after installing the ~~nonmethane cutter~~NMC. Repeat this verification within 185 days of testing to verify that the catalytic activity of the ~~cutter~~NMC has not deteriorated. Note that because ~~nonmethane cutters~~NMCs can deteriorate rapidly and without warning if they are operated outside of certain ranges of gas concentrations and outside of certain temperature ranges, good engineering judgment may dictate that you determine an ~~n nonmethane cutter~~NMC's penetration fractions more frequently.

(b) *Measurement principles.* A ~~nonmethane cutter~~NMC is a heated catalyst that removes nonmethane hydrocarbons from an exhaust sample stream before the FID analyzer measures the remaining hydrocarbon concentration. An ideal ~~nonmethane cutter~~NMC would have a CH<sub>4</sub> penetration fraction,  $PF_{CH_4}$ , of 1.000, and the penetration fraction for all other nonmethane hydrocarbons would be 0.000, as represented by  $PF_{C_2H_6}$ . The emission calculations in § 1065.660 use the measured values from this verification to account for less than ideal NMC performance.

(c) *System requirements.* We do not limit NMC penetration fractions to a certain range. However, we recommend that you optimize an ~~n NMC nonmethane cutter~~ by adjusting its temperature to achieve a  ~~$PF_{CH_4} > 0.85$  and a  $PF_{C_2H_6} < 0.02$~~ , as determined by paragraphs (d), (e), or (f) of this section, as applicable, ~~using dry gases~~. If we use an ~~n NMC nonmethane cutter~~ for testing, it will meet this recommendation. If adjusting NMC temperature does not result in achieving ~~both of these specifications simultaneously~~this recommendation, we recommend that you replace the catalyst material. Use the most recently determined penetration values from this section to calculate HC emissions according to § 1065.660 and § 1065.665 as applicable.

(d) *Procedure for a FID calibrated with the NMC.* The method described in this paragraph (d) is recommended over the procedures specified in paragraphs (e) and (f) of this section and required



for any gaseous-fueled engine, including dual-fuel and flexible-fuel engines. ~~If your FID arrangement is such that a FID is always calibrated to measure CH<sub>4</sub> with the NMC, then span that FID with the NMC using a CH<sub>4</sub> span gas, set the product of that FID's CH<sub>4</sub> response factor and CH<sub>4</sub> penetration fraction,  $RFPF_{CH_4[NMC-FID]}$ , equal to 1.0 for all emission calculations, and determine its combined C<sub>2</sub>H<sub>6</sub> response factor and C<sub>2</sub>H<sub>6</sub> penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ , as follows.~~ For any gaseous-fueled engine, including dual-fuel and flexible-fuel engines, you must determine the combined CH<sub>4</sub> response factor and penetration fraction,  $RFPF_{CH_4[NMC-FID]}$ , and combined C<sub>2</sub>H<sub>6</sub> response factor and C<sub>2</sub>H<sub>6</sub> penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ , as a function of the molar water concentration in the raw or diluted exhaust as described in paragraphs (d)(109) and (12g) of this section. Note that  $RFPF_{CH_4[NMC-FID]}$  is set equal to 1.0 only for zero molar water concentration. For any other engine you may use the same procedure, or you may set  $RFPF_{CH_4[NMC-FID]}$  equal to 1.0 and determine  $RFPF_{C_2H_6[NMC-FID]}$  at zero molar water concentration. Generate and verify the humidity generation as described in paragraph (dg)(11) of this section. ~~When using the option in this paragraph (d), note that the FID's CH<sub>4</sub> penetration fraction,  $PF_{CH_4[NMC-FID]}$ , is set equal to 1.0 only for 0 % molar water concentration. You are not required to meet the recommended lower limit for  $PF_{CH_4}$  of greater than 0.85 for any of the penetration fractions generated as a function of molar water concentration.~~

(1) Select CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> analytical gas mixtures and ensure that both mixtures meet the specifications of § 1065.750. Select a CH<sub>4</sub> concentration that you would use for spanning the FID during emission testing and select a C<sub>2</sub>H<sub>6</sub> concentration that is typical of the peak NMHC concentration expected at the hydrocarbon standard or equal to the THC analyzer's span value. For CH<sub>4</sub> analyzers with multiple ranges, perform this procedure on the highest range used for emission testing.

(2) Start, operate, and optimize the ~~nonmethane cutter~~NMC according to the manufacturer's instructions, including any temperature optimization.

(3) Confirm that the FID analyzer meets all the specifications of § 1065.360.

(4) Start and operate the FID analyzer according to the manufacturer's instructions.

(5) Zero and span the FID with the ~~nonmethane cutter~~NMC as you would during emission testing. Span the FID through the ~~cutter~~NMC by using CH<sub>4</sub> span gas.

(6) Introduce the C<sub>2</sub>H<sub>6</sub> analytical gas mixture upstream of the ~~nonmethane cutter~~NMC. Use good engineering judgment to address the effect of hydrocarbon contamination if your point of introduction is vastly different from the point of zero/span gas introduction.

(7) Allow time for the analyzer response to stabilize. Stabilization time may include time to purge the ~~nonmethane cutter~~NMC and to account for the analyzer's response.

(8) While the analyzer measures a stable concentration, record 30 seconds of sampled data. Calculate the arithmetic mean of these data points.

(9) Divide the mean C<sub>2</sub>H<sub>6</sub> concentration by the reference concentration of C<sub>2</sub>H<sub>6</sub>, converted to a C<sub>1</sub> basis and adjusted for water content, if necessary. The result is the ~~C<sub>2</sub>H<sub>6</sub>~~-combined C<sub>2</sub>H<sub>6</sub> response factor and penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ . Use this combined C<sub>2</sub>H<sub>6</sub> response factor and C<sub>2</sub>H<sub>6</sub> penetration fraction and the product of the CH<sub>4</sub> response factor and CH<sub>4</sub> penetration fraction,  $RFPF_{CH_4[NMC-FID]}$ , set to 1.0 in emission calculations according to § 1065.660(b)(2)(i) or (d)(1)(i) or § 1065.665, as applicable. If you are generating mixtures as a function of molar water concentration, follow the guidance in paragraph (g) of this section and repeat the steps in paragraphs (d)(6) to (9) of this section until all setpoints have been completed. Use  $RFPF_{C_2H_6[NMC-FID]}$  at the different setpoints to create a functional relationship between  $RFPF_{C_2H_6[NMC-FID]}$  and molar water concentration, downstream of the

last sample dryer if any sample dryers are present. Use this functional relationship to determine the combined response factor and penetration fraction during the emission test.

(10) If required by this paragraph (d), repeat the steps in paragraphs (d)(6) through (9) of this section, but with the CH<sub>4</sub> analytical gas mixture instead of C<sub>2</sub>H<sub>6</sub> and determine  $RFPF_{CH_4[NMC-FID]}$  instead.

(11) Use this combined C<sub>2</sub>H<sub>6</sub> response factor and penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ , and this combined CH<sub>4</sub> response factor and penetration fraction,  $RFPF_{CH_4[NMC-FID]}$ , in emission calculations according to §§ 1065.660(b)(2)(i) and 1065.660(d)(1)(i). Determine the combined C<sub>2</sub>H<sub>6</sub> response factor and C<sub>2</sub>H<sub>6</sub> penetration fraction as a function of molar water concentration and use it to account for C<sub>2</sub>H<sub>6</sub> response factor and C<sub>2</sub>H<sub>6</sub> penetration fraction for NMHC determination as described in § 1065.660(b)(2)(iii) and for CH<sub>4</sub> determination in § 1065.660(d)(1)(iii). Humidify the C<sub>2</sub>H<sub>6</sub> analytical gas mixture as described in paragraph (d)(11) of this section. Repeat the steps in paragraphs (d)(6) through (8) of this section until measurements are complete for each setpoint in the selected range. Divide each mean measured C<sub>2</sub>H<sub>6</sub> concentration by the reference concentration of C<sub>2</sub>H<sub>6</sub>, converted to a C<sub>1</sub>-basis and adjusted for water content to determine the FID analyzer's combined C<sub>2</sub>H<sub>6</sub> response factor and C<sub>2</sub>H<sub>6</sub> penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ . Use  $RFPF_{C_2H_6[NMC-FID]}$  at the different setpoints to create a functional relationship between the combined response factor and penetration fraction and molar water concentration, downstream of the last sample dryer if any sample dryers are present. Use this functional relationship to determine the combined response factor and penetration fraction during the emission test.

~~(11) Create a humidified test gas by bubbling the analytical gas mixture that meets the specifications in § 1065.750 through distilled H<sub>2</sub>O in a sealed vessel or use a device that introduces distilled H<sub>2</sub>O as vapor into a controlled gas flow. If the sample does not pass through a dryer during emission testing, generate at least five different H<sub>2</sub>O concentrations that cover the range from less than the minimum expected to greater than the maximum expected water concentration during testing. Use good engineering judgment to determine the target concentrations. For analyzers where the sample passes through a dryer during emission testing, humidify your test gas to an H<sub>2</sub>O level at or above the level determined in § 1065.145(e)(2) for that dryer and determine a single wet analyzer response to the dehumidified sample. Heat all transfer lines from the water generation system to a temperature at least 5 °C higher than the highest dewpoint generated. Determine H<sub>2</sub>O concentration as an average value over intervals of at least 30 seconds. Monitor the humidified sample stream with a dewpoint analyzer, relative humidity sensor, FTIR, NDIR, or other water analyzer during each test or, if the humidity generator achieves humidity levels with controlled flow rates, validate the instrument within 370 days before testing and after major maintenance using one of the following methods:~~

~~(i) Determine the linearity of each flow metering device. Use one or more reference flow meters to measure the humidity generator's flow rates and verify the H<sub>2</sub>O level value based on the humidity generator manufacturer's recommendations and good engineering judgment. We recommend that you utilize at least 10 flow rates for each flow metering device.~~

~~(ii) Perform validation testing based on monitoring the humidified stream with a dewpoint analyzer, relative humidity sensor, FTIR, NDIR, or other water analyzer as described in this paragraph (d)(11). Compare the measured humidity to the humidity generator's value. Verify overall linearity performance for the generated humidity as described in § 1065.307 using the criteria for other dewpoint measurements or confirm all measured values are within~~

~~± 2 % of the target mole fraction. In the case of dry gas, the measured value may not exceed 0.002 mole fraction.~~

~~(iii) Follow the performance requirements in § 1065.307(b) if the humidity generator does not meet validation criteria.~~

~~(12) Determine the CH<sub>4</sub> penetration fraction as a function of molar water concentration and use this penetration fraction for NMHC determination in § 1065.660(b)(2)(iii) and for CH<sub>4</sub> determination in § 1065.660(d)(1)(iii). Repeat the steps in paragraphs (d)(6) through (11) of this section, but with the CH<sub>4</sub> analytical gas mixture instead of C<sub>2</sub>H<sub>6</sub>. Use this functional relationship to determine the penetration fraction during the emission test.~~

(e) *Procedure for a FID calibrated with propane, bypassing the NMC.* If you use a single FID for THC and CH<sub>4</sub> determination with an NMC that is calibrated with propane, C<sub>3</sub>H<sub>8</sub>, by bypassing the NMC, determine its penetration fractions,  $PF_{C_2H_6[NMC-FID]}$  and  $PF_{CH_4[NMC-FID]}$ , as follows:

(1) Select CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> analytical gas mixtures and ensure that both mixtures meet the specifications of § 1065.750. Select a CH<sub>4</sub> concentration that you would use for spanning the FID during emission testing and select a C<sub>2</sub>H<sub>6</sub> concentration that is typical of the peak NMHC concentration expected at the hydrocarbon standard and the C<sub>2</sub>H<sub>6</sub> concentration typical of the peak total hydrocarbon (THC) concentration expected at the hydrocarbon standard or equal to the THC analyzer's span value. For CH<sub>4</sub> analyzers with multiple ranges, perform this procedure on the highest range used for emission testing.

(2) Start and operate the ~~nonmethane cutter~~NMC according to the manufacturer's instructions, including any temperature optimization.

(3) Confirm that the FID analyzer meets all the specifications of § 1065.360.

(4) Start and operate the FID analyzer according to the manufacturer's instructions.

(5) Zero and span the FID as you would during emission testing. Span the FID by bypassing the ~~cutter~~NMC and by using C<sub>3</sub>H<sub>8</sub> span gas. Note that you must span the FID on a C<sub>1</sub> basis. For example, if your span gas has a propane reference value of 100 µmol/mol, the correct FID response to that span gas is 300 µmol/mol because there are three carbon atoms per C<sub>3</sub>H<sub>8</sub> molecule.

(6) Introduce the C<sub>2</sub>H<sub>6</sub> analytical gas mixture upstream of the ~~nonmethane cutter~~NMC. Use good engineering judgment to address the effect of hydrocarbon contamination if your point of introduction is vastly different from the point of zero/span gas introduction.

(7) Allow time for the analyzer response to stabilize. Stabilization time may include time to purge the ~~nonmethane cutter~~NMC and to account for the analyzer's response.

(8) While the analyzer measures a stable concentration, record 30 seconds of sampled data. Calculate the arithmetic mean of these data points.

(9) Reroute the flow path to bypass the ~~nonmethane cutter~~NMC, introduce the C<sub>2</sub>H<sub>6</sub> analytical gas mixture, and repeat the steps in paragraphs (e)(7) through (8) of this section.

(10) Divide the mean C<sub>2</sub>H<sub>6</sub> concentration measured through the ~~nonmethane cutter~~NMC by the mean C<sub>2</sub>H<sub>6</sub> concentration measured after bypassing the ~~nonmethane cutter~~NMC. The result is the C<sub>2</sub>H<sub>6</sub> penetration fraction,  $PF_{C_2H_6[NMC-FID]}$ . Use this penetration fraction according to § 1065.660(b)(2)(ii), § 1065.660(d)(1)(ii), or § 1065.665, as applicable.

(11) Repeat the steps in paragraphs (e)(6) through (10) of this section, but with the CH<sub>4</sub> analytical gas mixture instead of C<sub>2</sub>H<sub>6</sub>. The result will be the CH<sub>4</sub> penetration fraction,  $PF_{CH_4[NMC-FID]}$ . Use this penetration fraction according to § 1065.660(b)(2)(ii) or § 1065.665, as applicable.

(f) *Procedure for a FID calibrated with CH<sub>4</sub>, bypassing the NMC.* If you use a FID with an NMC that is calibrated with CH<sub>4</sub>, by bypassing the NMC, determine its combined ~~ethane~~ (C<sub>2</sub>H<sub>6</sub>) response factor and penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ , as well as its CH<sub>4</sub> penetration fraction,  $PF_{CH_4[NMC-FID]}$ , as follows:

(1) Select CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> analytical gas mixtures and ensure that both mixtures meet the specifications of § 1065.750. Select a CH<sub>4</sub> concentration that you would use for spanning the FID during emission testing and select a C<sub>2</sub>H<sub>6</sub> concentration that is typical of the peak NMHC concentration expected at the hydrocarbon standard or equal to the THC analyzer's span value. For CH<sub>4</sub> analyzers with multiple ranges, perform this procedure on the highest range used for emission testing.

(2) Start and operate the ~~nonmethane cutter~~NMC according to the manufacturer's instructions, including any temperature optimization.

(3) Confirm that the FID analyzer meets all the specifications of § 1065.360.

(4) Start and operate the FID analyzer according to the manufacturer's instructions.

(5) Zero and span the FID as you would during emission testing. Span the FID by bypassing the ~~cutter~~NMC and by using CH<sub>4</sub> span gas.

(6) Introduce the C<sub>2</sub>H<sub>6</sub> analytical gas mixture upstream of the ~~nonmethane cutter~~NMC. Use good engineering judgment to address the effect of hydrocarbon contamination if your point of introduction is vastly different from the point of zero/span gas introduction.

(7) Allow time for the analyzer response to stabilize. Stabilization time may include time to purge the ~~nonmethane cutter~~NMC and to account for the analyzer's response.

(8) While the analyzer measures a stable concentration, record 30 seconds of sampled data. Calculate the arithmetic mean of these data points.

(9) Divide the mean C<sub>2</sub>H<sub>6</sub> concentration by the reference concentration of C<sub>2</sub>H<sub>6</sub>, converted to a C<sub>1</sub> basis. The result is the combined C<sub>2</sub>H<sub>6</sub> response factor and C<sub>2</sub>H<sub>6</sub> penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ . Use this combined C<sub>2</sub>H<sub>6</sub> response factor and ~~C<sub>2</sub>H<sub>6</sub>~~ penetration fraction according to § 1065.660(b)(2)(iii) or (d)(1)(iii) or § 1065.665, as applicable.

(10) Introduce the CH<sub>4</sub> analytical gas mixture upstream of the ~~nonmethane cutter~~NMC. Use good engineering judgment to address the effect of hydrocarbon contamination if your point of introduction is vastly different from the point of zero/span gas introduction.

(11) Allow time for the analyzer response to stabilize. Stabilization time may include time to purge the ~~nonmethane cutter~~NMC and to account for the analyzer's response.

(12) While the analyzer measures a stable concentration, record 30 seconds of sampled data. Calculate the arithmetic mean of these data points.

(13) Reroute the flow path to bypass the ~~nonmethane cutter~~NMC, introduce the CH<sub>4</sub> analytical gas mixture, and repeat the steps in paragraphs (e)(11) and (12) of this section.

(14) Divide the mean CH<sub>4</sub> concentration measured through the ~~nonmethane cutter~~NMC by the mean CH<sub>4</sub> concentration measured after bypassing the ~~nonmethane cutter~~NMC. The result is the CH<sub>4</sub> penetration fraction,  $PF_{CH_4[NMC-FID]}$ . Use this CH<sub>4</sub> penetration fraction according to § 1065.660(b)(2)(iii) or (d)(1)(iii) or § 1065.665, as applicable.

(g) *Test gas humidification.* If you are generating gas mixtures as a function of the molar water concentration in the raw or diluted exhaust according to paragraph (d) of this section, then create a humidified test gas by bubbling the analytical gas mixture that meets the specifications in § 1065.750 through distilled H<sub>2</sub>O in a sealed vessel or use a device that introduces distilled H<sub>2</sub>O as vapor into a controlled gas flow. Determine H<sub>2</sub>O concentration as an average value over intervals of at least 30 seconds. We recommend that you design your system so the wall temperatures in the transfer lines, fittings, and valves from the point where the mole fraction of

H<sub>2</sub>O in the humidified calibration gas,  $x_{H_2Oref}$ , is measured to the analyzer are at least 5 °C above the local calibration gas dewpoint. Verify the humidity generator's uncertainty upon initial installation, within 370 days before verifying response factors and penetration fractions, and after major maintenance. Use the uncertainties from the calibration of the humidity generator's measurements and follow NIST Technical Note 1297 (incorporated by reference in § 1065.1010) to verify that the amount of H<sub>2</sub>O in  $x_{H_2Oref}$  is determined within ±3 % uncertainty,  $U_{xH_2O}$ , for one of the options described in § 1065.750(a)(6)(i) or (ii). If the humidity generator requires assembly before use, after assembly follow the instrument manufacturer's instructions to check for leaks.

(1) If the sample does not pass through a dryer during emission testing, generate at least five different H<sub>2</sub>O concentrations that cover the range from less than the minimum expected to greater than the maximum expected water concentration during testing. Use good engineering judgment to determine the target concentrations.

(2) If the sample passes through a dryer during emission testing, humidify your test gas to an H<sub>2</sub>O level at or above the level determined in § 1065.145(e)(2) for that dryer and determine a single wet analyzer response to the dehumidified sample.

115. Amend § 1065.366 by revising paragraph (b) to read as follows:

**§ 1065.366 Interference verification for FTIR analyzers.**

\* \* \* \* \*

(b) *Measurement principles.* ~~Interference gases~~Certain species can interfere with ~~certain~~ analyzers by causing a response similar to the target analyte. If the analyzer uses compensation algorithms that utilize measurements of other gases to meet this interference verification, simultaneously conduct these other measurements to test the compensation algorithms during the analyzer interference verification.

\* \* \* \* \*

NO<sub>x</sub> AND N<sub>2</sub>O MEASUREMENTS

116. Amend § 1065.375 by revising paragraphs (b) and (d)(9) to read as follows:

**§ 1065.375 Interference verification for N<sub>2</sub>O analyzers.**

\* \* \* \* \*

(b) *Measurement principles.* ~~Interference gases~~Certain species can positively interfere with ~~certain~~ analyzers by causing a response similar to N<sub>2</sub>O. If the analyzer uses compensation algorithms that utilize measurements of other gases to meet this interference verification, simultaneously conduct these other measurements to test the compensation algorithms during the analyzer interference verification.

\* \* \* \* \*

(d) \* \* \*

(9) You may also run interference procedures separately for individual interference ~~gases~~species. If the concentration of the interference ~~gas levels~~species used are higher than the maximum levels expected during testing, you may scale down each observed interference value (the arithmetic mean of 30 second data described in paragraph (d)(7) of this section) by multiplying the observed interference by the ratio of the maximum expected concentration value to the actual value used during this procedure. You may run separate interference concentrations of H<sub>2</sub>O (down to 0.025 mol/mol H<sub>2</sub>O content) that are lower than the maximum levels expected during testing, but you must scale up the observed H<sub>2</sub>O interference by multiplying the observed

interference by the ratio of the maximum expected H<sub>2</sub>O concentration value to the actual value used during this procedure. The sum of the scaled interference values must meet the tolerance for combined interference as specified in paragraph (c) of this section.

117. Add § 1065.377 to read as follows:

**§ 1065.377 Interference verification for NH<sub>3</sub> analyzers.**

(a) Scope and frequency. See § 1065.277 to determine whether you need to verify the amount of interference after initial analyzer installation and after major maintenance.

(b) Measurement principles. Certain species can positively interfere with analyzers by causing a response similar to NH<sub>3</sub>. If the analyzer uses compensation algorithms that utilize measurements of other gases to meet this interference verification, simultaneously conduct these other measurements to test the compensation algorithms during the analyzer interference verification.

(c) System requirements. Analyzers must have combined interference that is within (0.0 ±2.0) μmol/mol.

(d) Procedure. Perform the interference verification as follows:

(1) Start, operate, zero, and span the NH<sub>3</sub> analyzer as you would before an emission test. If the sample is passed through a dryer during emission testing, you may run this verification test with the dryer if it meets the requirements of § 1065.342. Operate the dryer at the same conditions as you will for an emission test. You may also run this verification test without the sample dryer.

(2) Create a humidified test gas using a multi component span gas that incorporates the target interference species and meets the specifications in § 1065.750 and a humidity generator device that introduces distilled H<sub>2</sub>O as vapor into a controlled gas flow. If the sample does not pass through a dryer during emission testing, humidify your test gas to an H<sub>2</sub>O level at or above the maximum expected during emission testing. If the sample passes through a dryer during emission testing, you must humidify your test gas to an H<sub>2</sub>O level at or above the level determined in § 1065.145(e)(2) for that dryer. Use interference span gas concentrations that are at least as high as the maximum expected during testing.

(3) Introduce the humidified interference test gas into the sample system. You may introduce it downstream of any sample dryer, if one is used during testing.

(4) If the sample is not passed through a dryer during this verification test, measure the H<sub>2</sub>O mole fraction,  $x_{H_2O}$ , of the humidified interference test gas as close as possible to the inlet of the analyzer. For example, measure dewpoint,  $T_{dew}$ , and absolute pressure,  $p_{total}$ , to calculate  $x_{H_2O}$ . Verify that the H<sub>2</sub>O content meets the requirement in paragraph (d)(2) of this section. If the sample is passed through a dryer during this verification test, you must verify that the H<sub>2</sub>O content of the humidified test gas downstream of the vessel meets the requirement in paragraph (d)(2) of this section based on either direct measurement of the H<sub>2</sub>O content (e.g., dewpoint and pressure) or an estimate based on the vessel pressure and temperature. Use good engineering judgment to estimate the H<sub>2</sub>O content. For example, you may use previous direct measurements of H<sub>2</sub>O content to verify the vessel's level of saturation.

(5) If a sample dryer is not used in this verification test, use good engineering judgment to prevent condensation in the transfer lines, fittings, or valves from the point where  $x_{H_2O}$  is measured to the analyzer. We recommend that you design your system so that the wall temperatures in the transfer lines, fittings, and valves from the point where  $x_{H_2O}$  is measured to the analyzer are at least 5 °C above the local sample gas dewpoint.

(6) Allow time for the analyzer response to stabilize. Stabilization time may include time to purge the transfer line and to account for analyzer response.

(7) While the analyzer measures the sample’s concentration, record its output for 30 seconds. Calculate the arithmetic mean of this data. When performed with all the gases simultaneously, this is the combined interference.

(8) The analyzer meets the interference verification if the result of paragraph (d)(7) of this section meets the tolerance in paragraph (c) of this section.

(9) You may also run interference procedures separately for individual interference species. If the concentration of the interference species used are higher than the maximum levels expected during testing, you may scale down each observed interference value (the arithmetic mean of 30 second data described in paragraph (d)(7) of this section) by multiplying the observed interference by the ratio of the maximum expected concentration value to the actual value used during this procedure. You may run separate interference concentrations of H<sub>2</sub>O (down to 0.025 mol/mol H<sub>2</sub>O content) that are lower than the maximum levels expected during testing, but you must scale up the observed H<sub>2</sub>O interference by multiplying the observed interference by the ratio of the maximum expected H<sub>2</sub>O concentration value to the actual value used during this procedure. The sum of the scaled interference values must meet the tolerance for combined interference as specified in paragraph (c) of this section.

## **Subpart F—Performing an Emission Test Over Specified Duty Cycles**

118. Amend § 1065.512 by revising paragraphs (b)(1) and (2) to read as follows:

### **§ 1065.512 Duty cycle generation.**

\* \* \* \* \*

(b) \* \* \*

(1) *Engine speed for variable-speed engines.* For variable-speed engines, normalized speed may be expressed as a percentage between warm idle speed,  $f_{\text{idle}}$ , and maximum test speed,  $f_{\text{ntest}}$ , or speed may be expressed by referring to a defined speed by name, such as “warm idle,” “intermediate speed,” or “A,” “B,” or “C” speed. Section 1065.610 describes how to transform these normalized values into a sequence of reference speeds,  $f_{\text{href}}$ . Running duty cycles with negative or small normalized speed values near warm idle speed may cause low-speed idle governors to activate and the engine torque to exceed the reference torque even though the operator demand is at a minimum. In such cases, we recommend controlling the dynamometer so it gives priority to follow the reference torque instead of the reference speed and let the engine govern the speed. Note that the cycle-validation criteria in § 1065.514 allow an engine to govern itself. This allowance permits you to test engines with enhanced-idle devices, ~~and~~ to simulate the effects of transmissions such as automatic transmissions, and for engines with speed derate intended to limit exhaust mass flowrate.

(i) -For example, an enhanced-idle device might be an idle speed value that is normally commanded only under cold-start conditions to quickly warm up the engine and aftertreatment devices. In this case, negative and very low normalized speeds will generate reference speeds below this higher enhanced-idle speed. Control the dynamometer so it gives priority to follow the reference torque, controlling the operator demand so it gives priority to follow reference speed and let the engine govern the speed when the operator demand is at minimum.

You may do either of the following when using enhanced-idle devices:

~~(i) Control the dynamometer so it gives priority to follow the reference torque, controlling the operator demand so it gives priority to follow reference speed and let the engine govern the speed when the operator demand is at minimum.~~

~~(iiA) While running an engine where the ECM broadcasts an enhanced-idle speed that is above the denormalized speed, use the broadcast speed as the reference speed. Use these new reference points for duty-cycle validation. This does not affect how you determine denormalized reference torque in paragraph (b)(2) of this section.~~

~~(iiB) If an ECM broadcast signal is not available, perform one or more practice cycles to determine the enhanced-idle speed as a function of cycle time. Generate the reference cycle as you normally would but replace any reference speed that is lower than the enhanced-idle speed with the enhanced-idle speed. This does not affect how you determine denormalized reference torque in paragraph (b)(2) of this section.~~

(ii) For example, an engine with power derate intended to limit exhaust mass flowrate might include controls that reduce engine speed under cold-start conditions, resulting in reduced exhaust flow that assists other aftertreatment thermal management technologies (e.g., electric heater). In this case, normalized speeds will generate reference speeds above this engine speed derate. Control the dynamometer so it gives priority to follow the reference speed, controlling the operator demand so it gives priority to follow reference torque. You may do one of the following, as specified, when using engine derate devices:

(A) While running an engine where the ECM broadcasts engine derate speed that is below the denormalized speed, use the broadcast speed as the reference speed. Use these new reference points for duty-cycle validation. This does not affect how you determine denormalized reference torque in paragraph (b)(2) of this section.

(B) If an ECM broadcast signal is not available, perform one or more practice cycles to determine the engine derate speed as a function of cycle time. Generate the reference cycle as you normally would but replace any reference speed that is greater than the engine derate speed with the engine derate speed. This does not affect how you determine denormalized reference torque in paragraph (b)(2) of this section.

(2) *Engine torque for variable-speed engines.* For variable-speed engines, normalized torque is expressed as a percentage of the mapped torque at the corresponding reference speed. Section 1065.610 describes how to transform normalized torques into a sequence of reference torques,  $T_{ref}$ . Section 1065.610 also describes special requirements for modifying transient duty cycles for variable-speed engines intended primarily for propulsion of a vehicle with an automatic or manual transmission. Section 1065.610 also describes under what conditions you may command  $T_{ref}$  greater than the reference torque you calculated from a normalized duty cycle, which permits you to command  $T_{ref}$  values that are limited by a declared minimum torque. For any negative torque commands, command minimum operator demand and use the dynamometer to control engine speed to the reference speed, but if reference speed is so low that the idle governor activates, we recommend using the dynamometer to control torque to zero, CITT, or a declared minimum torque as appropriate. Note that you may omit power and torque points during motoring from the cycle-validation criteria in § 1065.514. Also, use the maximum mapped torque at the minimum mapped speed as the maximum torque for any reference speed at or below the minimum mapped speed.

\* \* \* \* \*



119. Amend § 1065.530 by revising paragraphs (b)(4), (9), and (11) to read as follows:

**§ 1065.530 Emission test sequence.**

\* \* \* \* \*

(b) \* \* \*

(4) Pre-heat or pre-cool heat exchangers in the sampling system to within their operating temperature tolerances for a test interval.

\* \* \* \* \*

(9) Select gas analyzer ranges. You may automatically or manually switch gas analyzer ranges during a test interval only if switching is performed by changing the span over which the digital resolution of the instrument is applied. During a test interval you may not switch the gains of an analyzer's analog operational amplifier(s).

\* \* \* \* \*

(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 interval.

\* \* \* \* \*

**Subpart G—Calculations and Data Requirements**

120. Amend § 1065.601 by revising paragraph (c)(1)(i) and removing and reserving paragraph (c)(1)(ii) to read as follows:

**§ 1065.601 Overview.**

\* \* \* \* \*

(c) \* \* \*

(1) \* \* \*

(i) ISO 8178-~~14~~ Section 9.1.614.4, NO<sub>x</sub> Correction for Humidity and Temperature. See § 1065.670 for approved methods for humidity corrections.

(ii) ~~ISO 8178-1 Section 15.1, Particulate Correction Factor for Humidity~~[Reserved].

\* \* \* \* \*

121. Amend § 1065.602 by adding paragraph (m) to read as follows:

**§ 1065.602 Statistics.**

\* \* \* \* \*

(m) Median. Determine median, *M*, as described in this paragraph (m). Arrange the data points in the data set in increasing order where the smallest value is ranked 1, the second-smallest value is ranked 2, etc.

(1) For even numbers of data points:

(i) Determine the rank of the data point whose value is used to determine the median as follows:

$$i = \frac{N}{2}$$

Where:

*i* = an indexing variable that represents the rank of the data point whose value is used to determine the median.

*N* = the number of data points in the set.

Example:

$$N = 4$$

$$y_1 = 41.515$$

$$y_2 = 41.780$$

$$y_3 = 41.861$$

$$y_4 = 41.902$$

$$i = \frac{4}{2}$$

$$i = 2$$

(ii) Determine the median as the average of the data point  $i$  and the data point  $i + 1$  as follows:

$$M = \frac{y_i + y_{i+1}}{2}$$

Example:

$$y_2 = 41.780$$

$$y_3 = 41.861$$

$$M = \frac{41.780 + 41.861}{2}$$

$$M = 41.821$$

(2) For odd numbers of data points, determine the rank of the data point whose value is the median and the corresponding median value as follows:

$$i = \frac{N + 1}{2}$$

Where:

$i$  = an indexing variable that represents the rank of the data point whose value is the median.

$N$  = the number of data points in the set.

Example:

$$N = 3$$

$$y_1 = 41.515$$

$$y_2 = 41.780$$

$$y_3 = 41.861$$

$$i = \frac{3 + 1}{2}$$

$$i = 2$$

$$M = 41.780$$

122. Amend § 1065.655 by revising the section heading and paragraphs (a), (b)(4), and (e)(4) introductory text to read as follows:

**§ 1065.655 Chemical balances of carbon-containing fuel, DEF, intake air, and exhaust.**

(a) General. Chemical balances of fuel, intake air, and exhaust may be used to calculate flows, the amount of water in their flows, and the wet concentration of constituents in their flows. Use the chemical balance calculations in this section for carbon-containing fuels. For fuels other than carbon-containing fuels use the chemical balance calculations of section § 1065.656. With one flow rate of either fuel, intake air, or exhaust, you may use chemical balances to determine the flows of the other two. For example, you may use chemical balances along with either intake air

or fuel flow to determine raw exhaust flow. Note that chemical balance calculations allow measured values for the flow rate of diesel exhaust fluid for engines with urea-based selective catalytic reduction.

(b) \* \* \*

(4) The amount of water in a raw or diluted exhaust flow,  $x_{H_2O_{exh}}$ , when you do not measure the amount of water to correct for the amount of water removed by a sampling system. Note that you may not use the FTIR based water measurement method in § 1065.257 to determine  $x_{H_2O_{exh}}$ . Correct for removed water according to § 1065.659.

\* \* \* \* \*

(e) \* \* \*

(4) Calculate  $\alpha$ ,  $\beta$ ,  $\gamma$ , and  $\delta$  as described in this paragraph (e)(4) using the following equations: If your fuel mixture contains fuels other than carbon-containing fuel, then calculate those fuels's mass fractions  $w_H$ ,  $w_C$ ,  $w_O$ , and  $w_N$  as described in § 1065.656(d) and set the fuels's mass fraction  $w_S$  to zero. Calculate  $\alpha$ ,  $\beta$ ,  $\gamma$ , and  $\delta$  using the following equations:

\* \* \* \* \*

123. Add § 1065.656 to read as follows:

**§ 1065.656 Chemical balances of fuels other than carbon-containing fuel, DEF, intake air, and exhaust.**

(a) General. Chemical balances of fuel, DEF, intake air, and exhaust may be used to calculate flows, the amount of water in their flows, and the wet concentration of constituents in their flows. Use the chemical balance calculations in this section for fuels other than carbon-containing fuels. For carbon-containing fuels, use the chemical balance calculations in section § 1065.655, including any dual-fuels or flexible-fuels where one of the fuels contains carbon. With one flow rate of either fuel, intake air, or exhaust, you may use chemical balances to determine the flows of the other two. For example, you may use chemical balances along with either intake air or fuel flow to determine raw exhaust flow. Note that chemical balance calculations allow measured values for the flow rate of diesel exhaust fluid for engines with urea-based selective catalytic reduction.

(b) Procedures that require chemical balances. We require chemical balances when you determine the following:

(1) A value proportional to total work,  $\tilde{W}$  when you choose to determine brake-specific emissions as described in § 1065.650(f).

(2) Raw exhaust molar flow rate either from measured intake air molar flow rate or from fuel mass flow rate as described in paragraph (f) of this section.

(3) Raw exhaust molar flow rate from measured intake air molar flow rate and dilute exhaust molar flow rate as described in paragraph (g) of this section.

(4) The amount of water in a raw or diluted exhaust flow,  $x_{H_2O_{exh}}$ , when you do not measure the amount of water to correct for the amount of water removed by a sampling system. Correct for removed water according to § 1065.659.

(5) The calculated total dilution air flow when you do not measure dilution air flow to correct for background emissions as described in § 1065.667(c) and (d).

(c) Chemical balance procedure. The calculations for a chemical balance involve a system of equations that require iteration. We recommend using a computer to solve this system of equations. You must guess the initial values of two of the following quantities: the amount of water in the measured flow,  $x_{H_2O_{exhdry}}$ , the amount of hydrogen in the measured flow,  $x_{H_2_{exhdry}}$ , the fraction of dilution air in diluted exhaust,  $x_{dil/exhdry}$ , and the amount of intake air required to

produce actual combustion products per mole of dry exhaust,  $x_{\text{int/exhdry}}$ . You may use time-weighted mean values of intake air humidity and dilution air humidity in the chemical balance; as long as your intake air and dilution air humidities remain within tolerances of  $\pm 0.0025$  mol/mol of their respective mean values over the test interval. For each emission concentration,  $x$ , and amount of water,  $x_{\text{H}_2\text{Oexh}}$ , you must determine their completely dry concentrations,  $x_{\text{dry}}$  and  $x_{\text{H}_2\text{Oexhdry}}$ . You must also use your fuel mixture's atomic carbon-to-hydrogen ratio,  $\tau$ , oxygen-to-hydrogen ratio,  $\phi$ , and nitrogen-to-hydrogen ratio,  $\omega$ ; you may optionally account for diesel exhaust fluid (or other fluids injected into the exhaust), if applicable. You may calculate  $\tau$ ,  $\phi$ , and  $\omega$  based on measured fuel composition or based on measured fuel and diesel exhaust fluid (or other fluids injected into the exhaust) composition together, as described in paragraph (e) of this section. You may alternatively use any combination of default values and measured values as described in paragraph (e) of this section. Use the following steps to complete a chemical balance:

(1) Convert your measured concentrations such as,  $x_{\text{H}_2\text{Omeas}}$ ,  $x_{\text{O}_2\text{meas}}$ ,  $x_{\text{H}_2\text{meas}}$ ,  $x_{\text{NOmeas}}$ ,  $x_{\text{NO}_2\text{meas}}$ ,  $x_{\text{NH}_3\text{meas}}$ , and  $x_{\text{H}_2\text{Oint}}$ , to dry concentrations by dividing them by one minus the amount of water present during their respective measurements; for example:  $x_{\text{H}_2\text{Omeas}}$ ,  $x_{\text{H}_2\text{OxO}_2\text{meas}}$ ,  $x_{\text{H}_2\text{OxNOmeas}}$ , and  $x_{\text{H}_2\text{Oint}}$ . If the amount of water present during a "wet" measurement is the same as an unknown amount of water in the exhaust flow,  $x_{\text{H}_2\text{Oexh}}$ , iteratively solve for that value in the system of equations. If you measure only total  $\text{NO}_x$  and not  $\text{NO}$  and  $\text{NO}_2$  separately, use good engineering judgment to estimate a split in your total  $\text{NO}_x$  concentration between  $\text{NO}$  and  $\text{NO}_2$  for the chemical balances. For example, if you measure emissions from a stoichiometric combustion engine, you may assume all  $\text{NO}_x$  is  $\text{NO}$ . For a lean-burn combustion engine, you may assume that your molar concentration of  $\text{NO}_x$ ,  $x_{\text{NO}_x}$ , is 75 %  $\text{NO}$  and 25 %  $\text{NO}_2$ . For  $\text{NO}_2$  storage aftertreatment systems, you may assume  $x_{\text{NO}_x}$  is 25 %  $\text{NO}$  and 75 %  $\text{NO}_2$ . Note that for calculating the mass of  $\text{NO}_x$  emissions, you must use the molar mass of  $\text{NO}_2$  for the effective molar mass of all  $\text{NO}_x$  species, regardless of the actual  $\text{NO}_2$  fraction of  $\text{NO}_x$ .

(2) Enter the equations in paragraph (c)(4) of this section into a computer program to iteratively solve for  $x_{\text{H}_2\text{Oexhdry}}$ ,  $x_{\text{H}_2\text{exhdry}}$ ,  $x_{\text{dil/exhdry}}$ , and  $x_{\text{int/exhdry}}$ . Use good engineering judgment to guess initial values for  $x_{\text{H}_2\text{Oexhdry}}$ ,  $x_{\text{H}_2\text{exhdry}}$ ,  $x_{\text{dil/exhdry}}$ , and  $x_{\text{int/exhdry}}$ . We recommend guessing an initial amount of water that is about twice the amount of water in your intake or dilution air. We recommend guessing an initial amount of hydrogen of 0 mol/mol. We recommend guessing an initial  $x_{\text{int/exhdry}}$  of 1 mol/mol. We also recommend guessing an initial  $x_{\text{dil/exhdry}}$  of 0.8 mol/mol. Iterate values in the system of equations until the most recently updated guesses are all within  $\pm 1$  % or  $\pm 1$   $\mu\text{mol/mol}$ , whichever is larger, of their respective most recently calculated values.

(3) Use the following symbols and subscripts in the equations for performing the chemical balance calculations in this paragraph (c):

**Table 1 of § 1065.656—Symbols and Subscripts for Chemical Balance Equations**

$x_{\text{[emission]meas}}$	<u>A</u> amount of measured emission in the sample at the respective gas analyzer.
$x_{\text{[emission]exh}}$	<u>A</u> amount of emission per dry mole of exhaust.
$x_{\text{[emission]exhdry}}$	<u>A</u> amount of emission per dry mole of dry exhaust.
$x_{\text{H}_2\text{O[emission]meas}}$	<u>A</u> amount of H <sub>2</sub> O in sample at emission-detection location; measure or estimate these values according to § 1065.145(e)(2) .
$x_{\text{dil/exh}}$	<u>A</u> amount of dilution gas or excess air per mole of exhaust.
$x_{\text{dil/exhdry}}$	<u>A</u> amount of dilution gas and/or excess air per mole of dry exhaust.
$x_{\text{Hcombdry}}$	<u>A</u> amount of hydrogen from fuel and any injected fluids in the exhaust per mole of dry exhaust.
$x_{\text{int/exhdry}}$	<u>A</u> amount of intake air required to produce actual combustion products per mole of dry (raw or diluted) exhaust.
$x_{\text{raw/exhdry}}$	<u>A</u> amount of undiluted exhaust, without excess air, per mole of dry (raw or diluted) exhaust.
$x_{\text{CO}_2\text{int}}$	<u>A</u> amount of intake air CO <sub>2</sub> per mole of intake air.
$x_{\text{CO}_2\text{intdry}}$	<u>A</u> amount of intake air CO <sub>2</sub> per mole of dry intake air; you may use $x_{\text{CO}_2\text{intdry}} = 375 \mu\text{mol/mol}$ , but we recommend measuring the actual concentration in the intake air.
$x_{\text{H}_2\text{Oint}}$	<u>A</u> amount of H <sub>2</sub> O in the intake air, based on a humidity measurement of intake air.
$x_{\text{H}_2\text{Ointdry}}$	<u>A</u> amount of intake air H <sub>2</sub> O per mole of dry intake air.
$x_{\text{O}_2\text{int}}$	<u>A</u> amount of intake air O <sub>2</sub> per mole of intake air.
$x_{\text{CO}_2\text{dil}}$	<u>A</u> amount of dilution gas CO <sub>2</sub> per mole of dilution gas.
$x_{\text{CO}_2\text{dildry}}$	<u>A</u> amount of dilution gas CO <sub>2</sub> per mole of dry dilution gas; if you use air as diluent, you may use $x_{\text{CO}_2\text{dildry}} = 375 \mu\text{mol/mol}$ , but we recommend measuring the actual concentration in the dilution gas.
$x_{\text{H}_2\text{Odil}}$	<u>A</u> amount of dilution gas H <sub>2</sub> O per mole of dilution gas.
$x_{\text{H}_2\text{Odildry}}$	<u>A</u> amount of dilution gas H <sub>2</sub> O per mole of dry dilution gas.
$\tau$	<u>A</u> atomic carbon-to-hydrogen ratio of the fuel (or mixture of test fuels) and any injected fluids.
$\varphi$	<u>A</u> atomic oxygen-to-hydrogen ratio of the fuel (or mixture of test fuels) and any injected fluids.
$\omega$	<u>A</u> atomic nitrogen-to-hydrogen ratio of the fuel (or mixture of test fuels) and any injected fluids.

(4) Use the equations specified in this section to iteratively solve for  $x_{\text{int/exhdry}}$ ,  $x_{\text{dil/exhdry}}$ ,  $x_{\text{H}_2\text{exhdry}}$ , and  $x_{\text{H}_2\text{Oexhdry}}$ . For some quantities multiple equations are provided. The calculation of  $x_{\text{O}_2\text{exhdry}}$  is only required when  $x_{\text{O}_2\text{meas}}$  is measured. The calculation of  $x_{\text{NH}_3\text{exhdry}}$  is only required for engines that use ammonia as fuel, for all other fuels  $x_{\text{NH}_3\text{exhdry}}$  may be set to zero.

$$x_{\text{dil/exh}} = 1 - \frac{x_{\text{raw/exhdry}}}{1 + x_{\text{H}_2\text{Oexhdry}}}$$

Eq. 1065.656-1

$$x_{\text{dil/exhdry}} = \frac{x_{\text{dil/exh}}}{1 - x_{\text{H}_2\text{Oexh}}}$$

Eq. 1065.656-2

$$x_{\text{H}_2\text{exhdry}} = \frac{x_{\text{H}_2\text{meas}}}{1 - x_{\text{H}_2\text{OH}_2\text{meas}}}$$

Eq. 1065.656-3 (see Table 2 of § 1065.656)

$$x_{\text{H}_2\text{exhdry}} = 2 \cdot (x_{\text{raw/exhdry}} - x_{\text{int/exhdry}}) - \left(\frac{1}{2} + \varphi + \omega\right) \cdot x_{\text{Hcombdry}} + \frac{1}{2} \cdot x_{\text{NH}_3\text{exhdry}} + x_{\text{NO}_2\text{exhdry}}$$

Eq. 1065.656-4 (see Table 2 of § 1065.656)

$$x_{\text{H}_2\text{Oexh}} = \frac{x_{\text{H}_2\text{Oexhdry}}}{1 + x_{\text{H}_2\text{Oexhdry}}}$$

Eq. 1065.656-5

$$x_{\text{H}_2\text{Oexhdry}} = \frac{x_{\text{H}_2\text{Omeas}}}{1 - x_{\text{H}_2\text{Omeas}}}$$

Eq. 1065.656-6 (see Table 2 of § 1065.656)

$$x_{\text{H}_2\text{Oexhdry}} = \frac{1}{2} \cdot x_{\text{Hcombdry}} - x_{\text{H}_2\text{exhdry}} - \frac{3}{2} \cdot x_{\text{NH}_3\text{exhdry}} + x_{\text{H}_2\text{Odil}} \cdot x_{\text{dil/exhdry}} + x_{\text{H}_2\text{Oint}} \cdot x_{\text{int/exhdry}}$$

Eq. 1065.656-7 (see Table 2 of § 1065.656)

$$x_{\text{Hcombdry}} = 2 \cdot x_{\text{H}_2\text{Oexhdry}} + 2 \cdot x_{\text{H}_2\text{exhdry}} + 3 \cdot x_{\text{NH}_3\text{exhdry}} - 2 \cdot x_{\text{H}_2\text{Odil}} \cdot x_{\text{dil/exhdry}} - 2 \cdot x_{\text{H}_2\text{Oint}} \cdot x_{\text{int/exhdry}}$$

Eq. 1065.656-8 (see Table 2 of § 1065.656)

$$x_{\text{Hcombdry}} = \frac{2 \cdot (x_{\text{raw/exhdry}} - x_{\text{int/exhdry}}) - x_{\text{H}_2\text{exhdry}} + \frac{1}{2} \cdot x_{\text{NH}_3\text{exhdry}} + x_{\text{NO}_2\text{exhdry}}}{\frac{1}{2} + \varphi + \omega}$$

Eq. 1065.656-9 (see Table 2 of § 1065.656)

$$x_{\text{int/exhdry}} = \frac{1}{2 \cdot x_{\text{O}_2\text{int}}} \cdot \left( \left( 2 \cdot \tau + \frac{1}{2} - \varphi \right) \cdot x_{\text{Hcombdry}} - x_{\text{H}_2\text{exhdry}} - \frac{3}{2} \cdot x_{\text{NH}_3\text{exhdry}} + x_{\text{NOexhdry}} + 2 \cdot x_{\text{NO}_2\text{exhdry}} \right)$$

Eq. 1065.656-10

$$x_{\text{NH}_3\text{exhdry}} = \frac{x_{\text{NH}_3\text{meas}}}{1 - x_{\text{H}_2\text{ONH}_3\text{meas}}}$$

Eq. 1065.656-11

$$x_{\text{NOexhdry}} = \frac{x_{\text{NOmeas}}}{1 - x_{\text{H}_2\text{ONomeas}}}$$

Eq. 1065.656-12

$$x_{\text{NO}_2\text{exhdry}} = \frac{x_{\text{NO}_2\text{meas}}}{1 - x_{\text{H}_2\text{ONO}_2\text{meas}}}$$

Eq. 1065.656-13

$$x_{\text{O}_2\text{exhdry}} = \frac{x_{\text{O}_2\text{meas}}}{1 - x_{\text{H}_2\text{OO}_2\text{meas}}}$$

Eq. 1065.656-14 (see Table 2 of § 1065.656)

$$x_{\text{raw/exhdry}} = 1 + x_{\text{H}_2\text{Oexhdry}} - \frac{1 + x_{\text{H}_2\text{O}dildry}}{0.209820 - x_{\text{CO}_2dildry}} \cdot x_{\text{O}_2\text{exhdry}}$$

Eq. 1065.656-15 (see Table 2 of § 1065.656)

$$x_{\text{raw/exhdry}} = \left( \frac{1}{4} + \frac{\varphi}{2} + \frac{\omega}{2} \right) \cdot x_{\text{H} \text{comb}dry} + \frac{1}{2} \cdot x_{\text{H}_2\text{exhdry}} - \frac{1}{4} \cdot x_{\text{NH}_3\text{exhdry}} - \frac{1}{2} x_{\text{NO}_2\text{exhdry}} + x_{\text{int/exhdry}}$$

Eq. 1065.656-16 (see Table 2 of § 1065.656)

$$x_{\text{CO}_2\text{int}dry} = \frac{x_{\text{CO}_2\text{int}}}{1 - x_{\text{H}_2\text{O}int}}$$

Eq. 1065.656-17

$$x_{\text{H}_2\text{O}int}dry = \frac{x_{\text{H}_2\text{O}int}}{1 - x_{\text{H}_2\text{O}int}}$$

Eq. 1065.656-18

$$x_{\text{O}_2int} = \frac{0.209820 - x_{\text{CO}_2\text{int}dry}}{1 + x_{\text{H}_2\text{O}int}dry}$$

Eq. 1065.656-19

$$x_{\text{CO}_2dildry} = \frac{x_{\text{CO}_2dil}}{1 - x_{\text{H}_2\text{O}dil}}$$

Eq. 1065.656-20

$$x_{\text{H}_2\text{O}dildry} = \frac{x_{\text{H}_2\text{O}dil}}{1 - x_{\text{H}_2\text{O}dil}}$$

Eq. 1065.656-21

(5) Depending on your measurements, use the equations and guess the quantities specified in Table 2 of this section:

Table 2 of § 1065.656—Chemical Balance Equations for Different Measurements

<u>When measuring...</u>	<u>gGuess...</u>	<u>Calculate...</u>
<u>(i) <math>x_{\text{O}_2\text{meas}}</math> and <math>x_{\text{H}_2\text{Omeas}}</math></u>	<u><math>x_{\text{int/exhdry}}</math> and <math>x_{\text{H}_2\text{exhdry}}</math></u>	<u>(A) <math>x_{\text{H}_2\text{exhdry}}</math> using Eq. 1065.656-4</u>
		<u>(B) <math>x_{\text{H}_2\text{Oexhdry}}</math> using Eq. 1065.656-6</u>
		<u>(C) <math>x_{\text{H} \text{comb}dry}</math> using Eq. 1065.656-8</u>
		<u>(D) <math>x_{\text{O}_2\text{exhdry}}</math> using Eq. 1065.656-14</u>
		<u>(E) <math>x_{\text{raw/exhdry}}</math> using Eq. 1065.656-15</u>
<u>(ii) <math>x_{\text{O}_2\text{meas}}</math> and <math>x_{\text{H}_2\text{meas}}</math></u>	<u><math>x_{\text{int/exhdry}}</math> and <math>x_{\text{H}_2\text{Oexhdry}}</math></u>	<u>(A) <math>x_{\text{H}_2\text{exhdry}}</math> using Eq. 1065.656-3</u>
		<u>(B) <math>x_{\text{H}_2\text{Oexhdry}}</math> using Eq. 1065.656-7</u>
		<u>(C) <math>x_{\text{H} \text{comb}dry}</math> using Eq. 1065.656-9</u>
		<u>(D) <math>x_{\text{O}_2\text{exhdry}}</math> using Eq. 1065.656-14</u>
		<u>(E) <math>x_{\text{raw/exhdry}}</math> using Eq. 1065.656-15</u>
<u>(iii) <math>x_{\text{H}_2\text{Omeas}}</math> and <math>x_{\text{H}_2\text{meas}}</math></u>	<u><math>x_{\text{int/exhdry}}</math> and <math>x_{\text{dil/exhdry}}</math></u>	<u>(A) <math>x_{\text{H}_2\text{exhdry}}</math> using Eq. 1065.656-3</u>
		<u>(B) <math>x_{\text{H}_2\text{Oexhdry}}</math> using Eq. 1065.656-6</u>
		<u>(C) <math>x_{\text{H} \text{comb}dry}</math> using Eq. 1065.656-8</u>
		<u>(D) <math>x_{\text{raw/exhdry}}</math> using Eq. 1065.656-16</u>

(d) Mass fractions of fuel. Determine the mass fractions of fuel,  $w_{\text{H}}$ ,  $w_{\text{C}}$ ,  $w_{\text{O}}$ , and  $w_{\text{N}}$ , based on the fuel properties as determined in paragraph (e) of this section, optionally accounting for diesel

exhaust fluid's contribution to  $\tau$ ,  $\phi$ , and  $\omega$ , or other fluids injected into the exhaust, if applicable (for example, the engine is equipped with an emission control system that utilizes DEF).

Calculate  $w_H$ ,  $w_C$ ,  $w_O$ , and  $w_N$  using the following equations:

$$w_H = \frac{1 \cdot M_H}{1 \cdot M_H + \tau \cdot M_C + \phi \cdot M_O + \omega \cdot M_N}$$

Eq. 1065.656-22

$$w_C = \frac{\tau \cdot M_C}{1 \cdot M_H + \tau \cdot M_C + \phi \cdot M_O + \omega \cdot M_N}$$

Eq. 1065.656-23

$$w_O = \frac{\phi \cdot M_O}{1 \cdot M_H + \tau \cdot M_C + \phi \cdot M_O + \omega \cdot M_N}$$

Eq. 1065.656-24

$$w_N = \frac{\omega \cdot M_N}{1 \cdot M_H + \tau \cdot M_C + \phi \cdot M_O + \omega \cdot M_N}$$

Eq. 1065.656-25

Where:

$w_H$  = hydrogen mass fraction of the fuel (or mixture of test fuels) and any injected fluids.

$w_C$  = carbon mass fraction of the fuel (or mixture of test fuels) and any injected fluids.

$w_O$  = oxygen mass fraction of the fuel (or mixture of test fuels) and any injected fluids.

$w_N$  = nitrogen mass fraction of the fuel (or mixture of test fuels) and any injected fluids.

$M_H$  = molar mass of hydrogen.

$\tau$  = atomic carbon-to- hydrogen ratio of the fuel (or mixture of test fuels) and any injected fluids.

$M_C$  = molar mass of carbon.

$\phi$  = atomic oxygen-to-hydrogen ratio of the fuel (or mixture of test fuels) and any injected fluids.

$M_O$  = molar mass of oxygen.

$\omega$  = atomic sulfur-to-hydrogen ratio of the fuel (or mixture of test fuels) and any injected fluids.

$M_N$  = molar mass of nitrogen.

(e) Fuel and diesel exhaust fluid composition. Determine fuel and diesel exhaust fluid composition represented by  $\tau$ ,  $\phi$ , and  $\omega$ , as described in this paragraph (e). When using measured fuel or diesel exhaust fluid properties, you must determine values for  $\tau$ ,  $\phi$ , and  $\omega$  in all cases. If you determine compositions based on measured values and the default value listed in Table 3 of this section is zero, you may set  $\tau$ ,  $\phi$ , and  $\omega$  to zero; otherwise determine  $\tau$ ,  $\phi$ , and  $\omega$  based on measured values. Determine elemental mass fractions and values for  $\tau$ ,  $\phi$ , and  $\omega$  as follows:

(1) For fuel and diesel exhaust fluid, use the default values for  $\tau$ ,  $\phi$ , and  $\omega$  in Table 3 of this section, or use good engineering judgment to determine those values based on measurement.

(2) For nonconstant fuel mixtures, you must account for the varying proportions of the different fuels. This paragraph (e)(2) generally applies for dual-fuel and flexible-fuel engines, but it also applies if diesel exhaust fluid is injected in a way that is not strictly proportional to fuel flow. Account for these varying concentrations either with a batch



measurement that provides averaged values to represent the test interval, or by analyzing data from continuous mass rate measurements. Application of average values from a batch measurement generally applies to situations where one fluid is a minor component of the total fuel mixture; consistent with good engineering judgment.

(4) Calculate  $\tau$ ,  $\phi$ , and  $\omega$  using the following equations:

$$\tau = \frac{M_H \cdot \sum_{j=1}^N \dot{m}_j \cdot w_{Cj}}{M_C \cdot \sum_{j=1}^N \dot{m}_j \cdot w_{Hj}}$$

Eq. 1065.656-26

$$\phi = \frac{M_H \cdot \sum_{j=1}^N \dot{m}_j \cdot w_{Oj}}{M_O \cdot \sum_{j=1}^N \dot{m}_j \cdot w_{Hj}}$$

Eq. 1065.656-27

$$\omega = \frac{M_H \cdot \sum_{j=1}^N \dot{m}_j \cdot w_{Nj}}{M_N \cdot \sum_{j=1}^N \dot{m}_j \cdot w_{Hj}}$$

Eq. 1065.656-28

Where:

$N$  = total number of fuels and injected fluids over the duty cycle.

$j$  = an indexing variable that represents one fuel or injected fluid, starting with  $j = 1$ .

$\dot{m}_j$  = the mass flow rate of the fuel or any injected fluid  $j$ . For applications using a single fuel and no DEF fluid, set this value to 1. For batch measurements, divide the total mass of fuel over the test interval duration to determine a mass rate.

$w_{Hj}$  = hydrogen mass fraction of fuel or any injected fluid  $j$ .

$w_{Cj}$  = carbon mass fraction of fuel or any injected fluid  $j$ .

$w_{Oj}$  = oxygen mass fraction of fuel or any injected fluid  $j$ .

$w_{Nj}$  = nitrogen mass fraction of fuel or any injected fluid  $j$ .

(4) Table 3 follows:

Table 3 of § 1065.656–Default Values of  $\tau$ ,  $\phi$ , and  $\omega$

<u>Fuel or injected fluid</u>	<u>Atomic carbon, oxygen, and nitrogen-to-hydrogen ratios</u> <u>HC<math>\tau</math>O<math>\phi</math>N<math>\omega</math></u>
<u>Hydrogen</u>	<u>HC<sub>0</sub>O<sub>0</sub>N<sub>0</sub></u>
<u>Ammonia</u>	<u>HC<sub>0</sub>O<sub>0</sub>N<sub>0.333</sub></u>
<u>Diesel exhaust fluid</u>	<u>HC<sub>0.056</sub>O<sub>0.444</sub>N<sub>0.112</sub></u>

(f) Calculated raw exhaust molar flow rate from measured intake air molar flow rate or fuel mass flow rate. You may calculate the raw exhaust molar flow rate from which you sampled emissions,  $\dot{n}_{\text{exh}}$ , based on the measured intake air molar flow rate,  $\dot{n}_{\text{int}}$ , or the measured fuel mass flow rate,  $\dot{m}_{\text{fuel}}$ , and the values calculated using the chemical balance in paragraph (c) of this section. The chemical balance must be based on raw exhaust gas concentrations. Solve for the chemical balance in paragraph (c) of this section at the same frequency that you update and record  $\dot{n}_{\text{int}}$  or  $\dot{m}_{\text{fuel}}$ . For laboratory tests, calculating raw exhaust molar flow rate using measured fuel mass flow rate is valid only for steady-state testing. See § 1065.915(d)(5)(iv) for application to field testing.

(1) Crankcase flow rate. If engines are not subject to crankcase controls under the standard-setting part, you may calculate raw exhaust flow based on  $\dot{n}_{\text{int}}$  or  $\dot{m}_{\text{fuel}}$  using one of the following:

- (i) You may measure flow rate through the crankcase vent and subtract it from the calculated exhaust flow.
- (ii) You may estimate flow rate through the crankcase vent by engineering analysis as long as the uncertainty in your calculation does not adversely affect your ability to show that your engines comply with applicable emission standards.
- (iii) You may assume your crankcase vent flow rate is zero.

(2) Intake air molar flow rate calculation. Calculate  $\dot{n}_{\text{exh}}$  based on  $\dot{n}_{\text{int}}$  using the following equation:

$$\dot{n}_{\text{exh}} = \frac{\dot{n}_{\text{int}}}{\left(1 + \frac{(x_{\text{int/exhdry}} - x_{\text{raw/exhdry}})}{(1 + x_{\text{H2Oexhdry}})}\right)}$$

Eq. 1065.656-29

Where:

$\dot{n}_{\text{exh}}$  = raw exhaust molar flow rate from which you measured emissions.

$\dot{n}_{\text{int}}$  = intake air molar flow rate including humidity in intake air.

Example:

$\dot{n}_{\text{int}} = 3.780$  mol/s

$x_{\text{int/exhdry}} = 0.69021$  mol/mol

$x_{\text{raw/exhdry}} = 1.10764$  mol/mol

$x_{\text{H2Oexhdry}} = 107.64$  mmol/mol = 0.10764 mol/mol

$$\dot{n}_{\text{exh}} = \frac{3.780}{\left(1 + \frac{(0.69021 - 1.10764)}{(1 + 0.10764)}\right)}$$

$\dot{n}_{\text{exh}} = 6.066$  mol/s

(3) Fluid mass flow rate calculation. This calculation may be used only for steady-state laboratory testing. See § 1065.915(d)(5)(iv) for application to field testing. Calculate  $\dot{n}_{\text{exh}}$  based on  $\dot{m}_j$  using the following equation:

$$\dot{n}_{\text{exh}} = \frac{1 + x_{\text{H2Oexhdry}}}{M_{\text{H}} \cdot x_{\text{Hcombdry}}} \cdot \sum_{j=1}^N \dot{m}_j \cdot w_{\text{H}j}$$

Eq. 1065.656-30

Where:

$\dot{n}_{\text{exh}}$  = raw exhaust molar flow rate from which you measured emissions.

$j$  = an indexing variable that represents one fuel or injected fluid, starting with  $j = 1$ .

$N$  = total number of fuels and injected fluids over the duty cycle.

$\dot{m}_j$  = the mass flow rate of the fuel or any injected fluid  $j$ .

$w_{\text{H}j}$  = hydrogen mass fraction of the fuel and any injected fluid  $j$ .

Example:

$x_{\text{H2Oexhdry1}} = 107.64$  mmol/mol = 0.10764 mol/mol

$M_{\text{H}} = 1.00794$  g/mol

$$\underline{x_{C_{comb}dry1} = 99.87 \text{ mmol/mol} = 0.09987 \text{ mol/mol}}$$

$$\underline{\dot{m}_1 = 7.559 \text{ g/s}}$$

$$\underline{w_{H1} = 0.07293 \text{ g/g}}$$

$$\underline{N = 1}$$

$$\underline{j = 1}$$

$$\dot{n}_{exh} = \frac{1 + 0.10764}{1.00794 \cdot 0.09987} \cdot 7.559 \cdot 0.07293$$

$$\underline{\dot{n}_{exh} = 6.066 \text{ mol/s}}$$

(g) Calculated raw exhaust molar flow rate from measured intake air molar flow rate, dilute exhaust molar flow rate, and dilute chemical balance. You may calculate the raw exhaust molar flow rate,  $\dot{n}_{exh}$ , based on the measured intake air molar flow rate,  $\dot{n}_{int}$ , the measured dilute exhaust molar flow rate,  $\dot{n}_{dexh}$ , and the values calculated using the chemical balance in paragraph (c) of this section. Note that the chemical balance must be based on dilute exhaust gas concentrations. For continuous-flow calculations, solve for the chemical balance in paragraph (c) of this section at the same frequency that you update and record  $\dot{n}_{int}$  and  $\dot{n}_{dexh}$ . This calculated  $\dot{n}_{dexh}$  may be used for the PM dilution ratio verification in § 1065.546; the calculation of dilution air molar flow rate in the background correction in § 1065.667; and the calculation of mass of emissions in § 1065.650(c) for species that are measured in the raw exhaust.

(1) Crankcase flow rate. If engines are not subject to crankcase controls under the standard-setting part, calculate raw exhaust flow as described in paragraph (f)(1) of this section.

(2) Dilute exhaust and intake air molar flow rate calculation. Calculate  $\dot{n}_{exh}$  as follows:

$$\dot{n}_{exh} = (x_{raw/exhdry} - x_{int/exhdry}) \cdot (1 - x_{H_2Oexh}) \cdot \dot{n}_{dexh} + \dot{n}_{int}$$

Eq. 1065.656-31

Example:

$$\dot{n}_{int} = 7.930 \text{ mol/s}$$

$$x_{raw/exhdry} = 0.1544 \text{ mol/mol}$$

$$x_{int/exhdry} = 0.1451 \text{ mol/mol}$$

$$x_{H_2Oexh} = 32.46 \text{ mmol/mol} = 0.03246 \text{ mol/mol}$$

$$\dot{n}_{dexh} = 49.02 \text{ mol/s}$$

$$\dot{n}_{exh} = (0.1544 - 0.1451) \cdot (1 - 0.03246) \cdot 49.02 + 7.930 = 0.4411 + 7.930 = 8.371 \text{ mol/s}$$

124. Amend § 1065.660 by revising paragraphs (b)(2) and (3) introductory text, (c)(1)(ii) and (2) introductory text, (d), and (e) to read as follows:

**§ 1065.660 THC, NMHC, NMNEHC, CH<sub>4</sub>, and C<sub>2</sub>H<sub>6</sub> determination.**

\* \* \* \* \*

(b) \* \* \*

(2) For a nonmethane cutter (NMC)s, calculate  $x_{NMHC}$  using the ~~nonmethane cutter~~NMC's penetration fractions, response factors, and/or combined penetration fractions and response factors as described in ~~methane penetration fraction,  $PF_{CH_4[NMC-FID]}$ , and the ethane response factor penetration fraction,  $RFPF_{C_2H_6[NMC-FID]}$ , from § 1065.365, the THC FID's methane CH<sub>4</sub> response factor,  $RF_{CH_4[THC-FID]}$ , from § 1065.360, the initial THC contamination and dry-to-wet corrected THC concentration,  $x_{THC[THC-FID]cor}$ , as determined in paragraph (a) of this section, and the dry-to-wet corrected ~~CH<sub>4</sub>methane~~ concentration,  $x_{THC[NMC-FID]cor}$ , optionally corrected for initial THC contamination as determined in paragraph (a) of this section.~~

(i) ~~If you need to account for penetration fractions determined as a function of molar water concentration, use Eq. 1065.660-4. Otherwise, use~~ the following equation for ~~penetration fractions determined using~~ an NMC configuration as ~~outlined described~~ in § 1065.365(d):

$$x_{\text{NMHC}} = \frac{x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} \cdot \text{RFPF}_{\text{CH}_4[\text{NMC-FID}]} - x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} \cdot \text{RF}_{\text{CH}_4[\text{THC-FID}]}}{\text{RFPF}_{\text{CH}_4[\text{NMC-FID}]} - \text{RFPF}_{\text{C}_2\text{H}_6[\text{NMC-FID}]} \cdot \text{RF}_{\text{CH}_4[\text{THC-FID}]}}$$

Eq. 1065.660-2

Where:

$x_{\text{NMHC}}$  = concentration of NMHC.

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination and dry-to-wet corrected, as measured by the THC FID during sampling while bypassing the NMC.

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination (optional) and dry-to-wet corrected, as measured by the NMC FID during sampling through the NMC.

$\text{RF}_{\text{CH}_4[\text{THC-FID}]}$  = response factor of THC FID to CH<sub>4</sub>, according to § 1065.360(d).

$\text{RFPF}_{\text{C}_2\text{H}_6[\text{NMC-FID}]}$  = ~~nonmethane cutter~~NMC combined C<sub>2</sub>H<sub>6</sub>ethane response factor and penetration fraction, according to § 1065.365(d).

$\text{RFPF}_{\text{CH}_4[\text{NMC-FID}]}$  = NMC combined CH<sub>4</sub> response factor and penetration fraction, according to § 1065.365(d).

*Example:*

$$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} = 150.3 \text{ } \mu\text{mol/mol}$$

$$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} = 20.5 \text{ } \mu\text{mol/mol}$$

$$\text{RFPF}_{\text{C}_2\text{H}_6[\text{NMC-FID}]} = 0.019$$

$$\text{RFPF}_{\text{CH}_4[\text{NMC-FID}]} = 1.000$$

$$\text{RF}_{\text{CH}_4[\text{THC-FID}]} = 1.05$$

$$x_{\text{NMHC}} = \frac{150.3 - 20.5 \cdot 1.05}{1 - 0.019 \cdot 1.05}$$

$$x_{\text{NMHC}} = 131.4 \text{ } \mu\text{mol/mol}$$

(ii) Use the following equation for penetration fractions determined using an NMC configuration as outlined in § 1065.365(e):

$$x_{\text{NMHC}} = \frac{x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} \cdot \text{PF}_{\text{CH}_4[\text{NMC-FID}]} - x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}}{\text{PF}_{\text{CH}_4[\text{NMC-FID}]} - \text{PF}_{\text{C}_2\text{H}_6[\text{NMC-FID}]}}$$

Eq. 1065.660-3

Where:

$x_{\text{NMHC}}$  = concentration of NMHC.

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination and dry-to-wet corrected, as measured by the THC FID during sampling while bypassing the NMC.

$\text{PF}_{\text{CH}_4[\text{NMC-FID}]}$  = ~~nonmethane cutter~~NMC CH<sub>4</sub> penetration fraction, according to § 1065.365(e).

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination (optional) and dry-to-wet corrected, as measured by the THC FID during sampling through the NMC.

$\text{PF}_{\text{C}_2\text{H}_6[\text{NMC-FID}]}$  = ~~nonmethane cutter ethane~~NMC C<sub>2</sub>H<sub>6</sub> penetration fraction, according to § 1065.365(e).

*Example:*

$$\begin{aligned}
x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} &= 150.3 \text{ } \mu\text{mol/mol} \\
PF_{\text{CH}_4[\text{NMC-FID}]} &= 0.990 \\
x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} &= 20.5 \text{ } \mu\text{mol/mol} \\
PF_{\text{C}_2\text{H}_6[\text{NMC-FID}]} &= 0.020 \\
x_{\text{NMHC}} &= \frac{150.3 \cdot 0.990 - 20.5}{0.990 - 0.020} \\
x_{\text{NMHC}} &= 132.3 \text{ } \mu\text{mol/mol}
\end{aligned}$$

(iii) Use the following equation for ~~penetration fractions determined using~~ an NMC configuration ~~as outlined described~~ in § 1065.365(f) ~~or for penetration fractions determined as a function of molar water concentration using an NMC configuration as outlined in § 1065.365(d)~~:

$$x_{\text{NMHC}} = \frac{x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} \cdot PF_{\text{CH}_4[\text{NMC-FID}]} - x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} \cdot RF_{\text{CH}_4[\text{THC-FID}]}}{PF_{\text{CH}_4[\text{NMC-FID}]} - RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]} \cdot RF_{\text{CH}_4[\text{THC-FID}]}}$$

Eq. 1065.660-4

Where:

$x_{\text{NMHC}}$  = concentration of NMHC.

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination and dry-to-wet corrected, as measured by the THC FID during sampling while bypassing the NMC.

$PF_{\text{CH}_4[\text{NMC-FID}]}$  = ~~nonmethane cutter~~NMC  $\text{CH}_4$  penetration fraction, according to § 1065.365(f).

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination (optional) and dry-to-wet corrected, as measured by the THC FID during sampling through the NMC.

$RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}$  = ~~nonmethane cutter~~CH<sub>4</sub>NMC combined C<sub>2</sub>H<sub>6</sub> ethane response factor and penetration fraction, according to § 1065.365(f).

$RF_{\text{CH}_4[\text{THC-FID}]}$  = response factor of THC FID to  $\text{CH}_4$ , according to § 1065.360(d).

*Example:*

$$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} = 150.3 \text{ } \mu\text{mol/mol}$$

$$PF_{\text{CH}_4[\text{NMC-FID}]} = 0.990$$

$$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} = 20.5 \text{ } \mu\text{mol/mol}$$

$$RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]} = 0.019$$

$$RF_{\text{CH}_4[\text{THC-FID}]} = 0.980$$

$$x_{\text{NMHC}} = \frac{150.3 \cdot 0.990 - 20.5 \cdot 0.980}{0.990 - 0.019 \cdot 0.980}$$

$$x_{\text{NMHC}} = 132.5 \text{ } \mu\text{mol/mol}$$

(3) For a GC-FID or FTIR, calculate  $x_{\text{NMHC}}$  using the THC analyzer's ~~methane~~CH<sub>4</sub> response factor,  $RF_{\text{CH}_4[\text{THC-FID}]}$ , from § 1065.360, and the initial THC contamination and dry-to-wet corrected THC concentration,  $x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$ , as determined in paragraph (a) of this section as follows:

\* \* \* \* \*

(c) \* \* \*

(1) \* \* \*

(ii) If the content of your fuel test contains at least 0.010 mol/mol of ~~ethane~~C<sub>2</sub>H<sub>6</sub>, you may omit the calculation of NMNEHC concentration and calculate the mass of NMNEHC as described in § 1065.650(c)(6)(ii).

(2) For a GC-FID, NMC FID, or FTIR, calculate  $x_{\text{NMNEHC}}$  using the THC analyzer's ~~CH<sub>4</sub>methane~~ response factor,  $RF_{\text{CH}_4[\text{THC-FID}]}$ , and C<sub>2</sub>H<sub>6</sub>ethane response factor,  $RF_{\text{C}_2\text{H}_6[\text{THC-FID}]}$ ,

from § 1065.360, the initial contamination and dry-to-wet corrected THC concentration,  $x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$ , as determined in paragraph (a) of this section, the dry-to-wet corrected ~~methane-CH<sub>4</sub>~~ concentration,  $x_{\text{CH}_4}$ , as determined in paragraph (d) of this section, and the dry-to-wet corrected ~~C<sub>2</sub>H<sub>6</sub>ethane~~ concentration,  $x_{\text{C}_2\text{H}_6}$ , as determined in paragraph (e) of this section as follows:

\* \* \* \* \*

(d) *CH<sub>4</sub> determination.* Use one of the following methods to determine methane (CH<sub>4</sub>) concentration,  $x_{\text{CH}_4}$ :

(1) For a nonmethane cutter (NMC)s, calculate  $x_{\text{CH}_4}$  using the ~~nonmethane-cutterNMC's methane~~ penetration fractions,  ~~$PF_{\text{CH}_4[\text{NMC-FID}]}$~~ , ~~and the ethane~~ response factors, ~~and/or combined~~ penetration fraction,  ~~$RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}$~~ , ~~froms and response factors as described in~~ § 1065.365, the THC FID's ~~CH<sub>4</sub>methane~~ response factor,  $RF_{\text{CH}_4[\text{THC-FID}]}$ , from § 1065.360, the initial THC contamination and dry-to-wet corrected THC concentration,  $x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$ , as determined in paragraph (a) of this section, and the dry-to-wet corrected ~~CH<sub>4</sub>methane~~ concentration,  $x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}$ , optionally corrected for initial THC contamination as determined in paragraph (a) of this section.

(i) ~~If you need to account for penetration fractions determined as a function of molar water concentration, use Eq. 1065.660-11. Otherwise, u~~Use the following equation for ~~penetration fractions determined using~~ an NMC configuration ~~as outlined-described~~ in § 1065.365(d):

$$x_{\text{CH}_4} = \frac{x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} - x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} \cdot RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}{RFPF_{\text{CH}_4[\text{NMC-FID}]} - RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]} \cdot RF_{\text{CH}_4[\text{THC-FID}]}}$$

Eq. 1065.660-9

Where:

$x_{\text{CH}_4}$  = concentration of CH<sub>4</sub>.

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination (optional) and dry-to-wet corrected, as measured by the NMC FID during sampling through the NMC.

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination and dry-to-wet corrected, as measured by the THC FID during sampling while bypassing the NMC.

$RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}$  = ~~the-NMC~~ combined ~~ethane-C<sub>2</sub>H<sub>6</sub>~~ response factor and penetration fraction ~~of the nonmethane-cutter~~, according to § 1065.365(d).

$RF_{\text{CH}_4[\text{THC-FID}]}$  = response factor of THC FID to CH<sub>4</sub>, according to § 1065.360(d).

$RFPF_{\text{CH}_4[\text{NMC-FID}]}$  = NMC combined CH<sub>4</sub> response factor and penetration fraction, according to § 1065.365(d).

*Example:*

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} = 10.4 \mu\text{mol/mol}$

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} = 150.3 \mu\text{mol/mol}$

$RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]} = 0.019$

$RFPF_{\text{CH}_4[\text{NMC-FID}]} = 1.000$

$RF_{\text{CH}_4[\text{THC-FID}]} = 1.05$

$$x_{\text{CH}_4} = \frac{10.4 - 150.3 \cdot 0.019}{1 - 0.019 \cdot 1.05}$$

$x_{\text{CH}_4} = 7.69 \mu\text{mol/mol}$

(ii) Use the following equation for ~~penetration fractions determined using~~ an NMC configuration as ~~outlined described~~ in § 1065.365(e):

$$x_{\text{CH}_4} = \frac{x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} - x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} \cdot PF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}}{RF_{\text{CH}_4[\text{THC-FID}]} \cdot (PF_{\text{CH}_4[\text{NMC-FID}]} - PF_{\text{C}_2\text{H}_6[\text{NMC-FID}]})}$$

Eq. 1065.660-10

Where:

$x_{\text{CH}_4}$  = concentration of  $\text{CH}_4$ .

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination (optional) and dry-to-wet corrected, as measured by the NMC FID during sampling through the NMC.

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination and dry-to-wet corrected, as measured by the THC FID during sampling while bypassing the NMC.

$PF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}$  = ~~nonmethane cutter ethane~~ NMC  $\text{C}_2\text{H}_6$  penetration fraction, according to § 1065.365(e).

$RF_{\text{CH}_4[\text{THC-FID}]}$  = response factor of THC FID to  $\text{CH}_4$ , according to § 1065.360(d).

$PF_{\text{CH}_4[\text{NMC-FID}]}$  = ~~nonmethane cutter~~ NMC  $\text{CH}_4$  penetration fraction, according to § 1065.365(e).

*Example:*

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} = 10.4 \text{ } \mu\text{mol/mol}$

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} = 150.3 \text{ } \mu\text{mol/mol}$

$PF_{\text{C}_2\text{H}_6[\text{NMC-FID}]} = 0.020$

$RF_{\text{CH}_4[\text{THC-FID}]} = 1.05$

$PF_{\text{CH}_4[\text{NMC-FID}]} = 0.990$

$$x_{\text{CH}_4} = \frac{10.4 - 150.3 \cdot 0.020}{1.05 \cdot (0.990 - 0.020)}$$

$x_{\text{CH}_4} = 7.25 \text{ } \mu\text{mol/mol}$

(iii) Use the following equation for ~~penetration fractions determined using~~ an NMC configuration as ~~outlined described~~ in § 1065.365(f) ~~or for penetration fractions determined as a function of molar water concentration using an NMC configuration as outlined in § 1065.365(d)~~:

$$x_{\text{CH}_4} = \frac{x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}} - x_{\text{THC}[\text{THC-FID}]_{\text{cor}}} \cdot RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}}{PF_{\text{CH}_4[\text{NMC-FID}]} - RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]} \cdot RF_{\text{CH}_4[\text{THC-FID}]}}$$

Eq. 1065.660-11

Where:

$x_{\text{CH}_4}$  = concentration of  $\text{CH}_4$ .

$x_{\text{THC}[\text{NMC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination (optional) and dry-to-wet corrected, as measured by the NMC FID during sampling through the NMC.

$x_{\text{THC}[\text{THC-FID}]_{\text{cor}}}$  = concentration of THC, initial THC contamination and dry-to-wet corrected, as measured by the THC FID during sampling while bypassing the NMC.

$RFPF_{\text{C}_2\text{H}_6[\text{NMC-FID}]}$  = the combined  $\text{C}_2\text{H}_6$  ~~ethane~~ response factor and penetration fraction of the ~~nonmethane cutter~~ NMC, according to § 1065.365(f).

$PF_{\text{CH}_4[\text{NMC-FID}]}$  = ~~nonmethane cutter~~ NMC  $\text{CH}_4$  penetration fraction, according to § 1065.365(f).

$RF_{CH_4[THC-FID]}$  = response factor of THC FID to CH<sub>4</sub>, according to § 1065.360(d).

*Example:*

$$\begin{aligned}x_{THC[NMC-FID]_{cor}} &= 10.4 \text{ } \mu\text{mol/mol} \\x_{THC[THC-FID]_{cor}} &= 150.3 \text{ } \mu\text{mol/mol} \\RPF_{C_2H_6[NMC-FID]} &= 0.019 \\PF_{CH_4[NMC-FID]} &= 0.990 \\RF_{CH_4[THC-FID]} &= 1.05 \\x_{CH_4} &= \frac{10.4 - 150.3 \cdot 0.019}{0.990 - 0.019 \cdot 1.05} \\x_{CH_4} &= 7.78 \text{ } \mu\text{mol/mol}\end{aligned}$$

(2) For a GC-FID or FTIR,  $x_{CH_4}$  is the actual dry-to-wet corrected ~~methane-CH<sub>4</sub>~~ concentration as measured by the analyzer.

(e) *C<sub>2</sub>H<sub>6</sub> determination.* For a GC-FID or FTIR,  $x_{C_2H_6}$  is the C<sub>1</sub>-equivalent, dry-to-wet corrected ~~ethane-C<sub>2</sub>H<sub>6</sub>~~ concentration as measured by the analyzer.

125. Amend § 1065.670 by revising paragraphs (a) introductory text and (b) introductory text to read as follows:

**§ 1065.670 NO<sub>x</sub> intake-air humidity and temperature corrections.**

\* \* \* \* \*

(a) For compression-ignition engines operating on carbon-containing fuels and lean-burn combustion engines operating on fuels other than carbon-containing fuels, correct for intake-air humidity using the following equation:

\* \* \* \* \*

(b) For spark-ignition engines operating on carbon-containing fuels and stoichiometric combustion engines operating on fuels other than carbon-containing fuels, correct for intake-air humidity using the following equation:

\* \* \* \* \*

**Subpart H—Engine Fluids, Test Fuels, Analytical Gases and Other Calibration Standards**

126. Amend § 1065.750 by revising paragraph (a)(1)(ii) and adding paragraph (a)(6) to read as follows:

**§ 1065.750 Analytical gases.**

\* \* \* \* \*

(a) \* \* \*

(1) \* \* \*

(ii) Contamination as specified in the following table:



Table 1 of § 1065.750–General Specifications for Purified Gases<sup>a</sup>

Constituent	Purified Air	Purified N <sub>2</sub>
THC (C <sub>1</sub> -equivalent)	≤ 0.05 μmol/mol	≤ 0.05 μmol/mol
CO	≤ 1 μmol/mol	≤ 1 μmol/mol
CO <sub>2</sub>	≤ 10 μmol/mol	≤ 10 μmol/mol
O <sub>2</sub>	0.205 to 0.215 mol/mol	≤ 2 μmol/mol
NO <sub>x</sub>	≤ 0.02 μmol/mol	≤ 0.02 μmol/mol
N <sub>2</sub> O <sup>b</sup>	≤ 0.02 μmol/mol	≤ 0.02 μmol/mol
<u>H<sub>2</sub><sup>c</sup></u>	<u>≤ 1 μmol/mol</u>	<u>≤ 1 μmol/mol</u>
<u>NH<sub>3</sub><sup>d</sup></u>	<u>≤ 1 μmol/mol</u>	<u>≤ 1 μmol/mol</u>
<u>H<sub>2</sub>O<sup>e</sup></u>	<u>≤ 5 μmol/mol</u>	<u>≤ 5 μmol/mol</u>

<sup>a</sup>We do not require these levels of purity to be NIST-traceable.

<sup>b</sup>The N<sub>2</sub>O limit applies only if the standard-setting part requires you to report N<sub>2</sub>O or certify to an N<sub>2</sub>O standard.

<sup>c</sup>The H<sub>2</sub> limit only applies for testing with H<sub>2</sub> fuel.

<sup>d</sup>The NH<sub>3</sub> limit only applies for testing with NH<sub>3</sub> fuel.

<sup>e</sup>The H<sub>2</sub>O limit only applies for water measurement according to § 1065.257.

\* \* \* \* \*

(6) If you measure H<sub>2</sub>O using an FTIR analyzer, generate H<sub>2</sub>O calibration gases with a humidity generator using one of the options in this paragraph (a)(6). Use good engineering judgment to prevent condensation in the transfer lines, fittings, or valves from the humidity generator to the FTIR analyzer. Design your system so the wall temperatures in the transfer lines, fittings, and valves from the point where the mole fraction of H<sub>2</sub>O in the humidified calibration gas,  $x_{H_2Oref}$ , is measured to the analyzer are at a temperature of (110 to 202) °C. Calibrate the humidity generator upon initial installation, within 370 days before verifying the H<sub>2</sub>O measurement of the FTIR, and after major maintenance. Use the uncertainties from the calibration of the humidity generator's measurements and follow NIST Technical Note 1297 (incorporated by reference in § 1065.1010) to verify that the amount of H<sub>2</sub>O in the calibration gas,  $x_{H_2Oref}$ , is determined within ±3 % uncertainty,  $U_{xH_2O}$ . If the humidity generator requires assembly before use, after assembly follow the instrument manufacturer's instructions to check for leaks. You may generate the H<sub>2</sub>O calibration gas using one of the following options:

(i) Bubble gas that meets the requirements of paragraph (a)(1) of this section through distilled H<sub>2</sub>O in a sealed vessel. Adjust the amount of H<sub>2</sub>O in the calibration gas by changing the temperature of the H<sub>2</sub>O in the sealed vessel. Determine absolute pressure,  $p_{abs}$ , and dewpoint,  $T_{dew}$ , of the humidified gas leaving the sealed vessel. Calculate the amount of H<sub>2</sub>O in the calibration gas as described in § 1065.645(a) and (b). Calculate the uncertainty of the amount of H<sub>2</sub>O in the calibration gas,  $U_{xH_2O}$ , using the following equations:

$$\frac{\partial x_{H_2O}}{\partial T_{dew}} = x_{H_2O} \cdot \left( \frac{6790.241 + 2.961487 \cdot 10^{4.76955 \cdot \left(1 - \frac{273.16}{T_{dew}}\right)}}{T_{dew}^2} - \frac{5.028}{T_{dew}} + 2.423229 \cdot 10^{-5} \cdot 10^{-8.2969 \cdot \left(\frac{T_{dew}}{273.16} - 1\right)} \right)$$

Eq. 1065.750-1

$$\frac{\partial x_{\text{H}_2\text{O}}}{\partial p_{\text{abs}}} = -1 \cdot \frac{x_{\text{H}_2\text{O}}}{p_{\text{abs}}}$$

Eq. 1065.750-2

$$U_{x_{\text{H}_2\text{O}}} = \sqrt{\left(\frac{\partial x_{\text{H}_2\text{O}}}{\partial p_{\text{abs}}} \cdot U_{p_{\text{abs}}}\right)^2 + \left(\frac{\partial x_{\text{H}_2\text{O}}}{\partial T_{\text{dew}}} \cdot U_{T_{\text{dew}}}\right)^2}$$

Eq. 1065.750-3

Where:

$T_{\text{dew}}$  = saturation temperature of water at measured conditions.

$U_{T_{\text{dew}}}$  = expanded uncertainty ( $k = 2$ ) of the measured saturation temperature of water at measured conditions.

$p_{\text{abs}}$  = wet static absolute pressure at the location of the dewpoint measurement.

$U_{p_{\text{abs}}}$  = expanded uncertainty ( $k = 2$ ) of the wet static absolute pressure at the location of the dewpoint measurement.

$\frac{\partial x_{\text{H}_2\text{O}}}{\partial T_{\text{dew}}}$  = partial derivative of  $x_{\text{H}_2\text{O}}$  with respect to  $T_{\text{dew}}$ .

$\frac{\partial x_{\text{H}_2\text{O}}}{\partial p_{\text{abs}}}$  = partial derivative of  $x_{\text{H}_2\text{O}}$  with respect to  $p_{\text{abs}}$ .

$x_{\text{H}_2\text{O}}$  = amount of water in the calibration gas.

$U_{x_{\text{H}_2\text{O}}}$  = expanded uncertainty ( $k = 2$ ) of the amount of  $\text{H}_2\text{O}$  in the calibration gas.

Example:

$$T_{\text{dew}} = 39.5 \text{ }^\circ\text{C} = 312.65 \text{ K}$$

$$U_{T_{\text{dew}}} = 0.390292 \text{ K}$$

$$p_{\text{abs}} = 99.980 \text{ kPa}$$

$$U_{p_{\text{abs}}} = 1.15340 \text{ kPa}$$

Using Eq. 1065.645-1,

$$x_{\text{H}_2\text{O}} = 0.0718436 \text{ mol/mol}$$

$$\frac{\partial x_{\text{H}_2\text{O}}}{\partial T_{\text{dew}}} = 0.0718436$$

$$\cdot \left( \frac{6790.241 + 2.961487 \cdot 10^{4.76955 \cdot \left(1 - \frac{273.16}{312.65}\right)}}{312.65^2} - \frac{5.028}{312.65} + 2.423229 \right. \\ \left. \cdot 10^{-5} \cdot 10^{-8.2969 \cdot \left(\frac{312.65}{273.16} - 1\right)} \right)$$

$$\frac{\partial x_{\text{H}_2\text{O}}}{\partial T_{\text{dew}}} = 0.00384409 \text{ (mol/mol)/K}$$

$$\frac{\partial x_{\text{H}_2\text{O}}}{\partial p_{\text{abs}}} = -1 \cdot \frac{0.0718436}{99.980}$$

$$\frac{\partial x_{\text{H}_2\text{O}}}{\partial p_{\text{abs}}} = -0.000718580 \text{ (mol/mol)/kPa}$$

$$U_{x_{\text{H}_2\text{O}}} = \sqrt{(-0.000718580 \cdot 1.15340)^2 + (0.00384409 \cdot 0.390292)^2}$$

$$U_{x_{\text{H}_2\text{O}}} = 0.00171402 \text{ mol/mol}$$

(ii) Use a device that introduces a measured flow of distilled H<sub>2</sub>O as vapor into a measured flow of gas that meets the requirements of paragraph (a)(1) of this section. Determine the molar flows of gas and H<sub>2</sub>O that are mixed to generate the calibration gas.

(A) Calculate the amount of H<sub>2</sub>O in the calibration gas as follows:

$$x_{\text{H}_2\text{O}} = \frac{\dot{n}_{\text{H}_2\text{O}}}{\dot{n}_{\text{gas}} + \dot{n}_{\text{H}_2\text{O}}}$$

Eq. 1065.750-4

(B) Calculate the uncertainty of the amount of H<sub>2</sub>O in the generated calibration gas,  $U_{x_{\text{H}_2\text{O}}}$ , using the following equations:

$$\frac{\partial x_{\text{H}_2\text{O}}}{\partial \dot{n}_{\text{gas}}} = -1 \cdot \frac{\dot{n}_{\text{H}_2\text{O}}}{(\dot{n}_{\text{gas}} + \dot{n}_{\text{H}_2\text{O}})^2}$$

Eq. 1065.750-5

$$\frac{\partial x_{\text{H}_2\text{O}}}{\partial \dot{n}_{\text{H}_2\text{O}}} = \frac{\dot{n}_{\text{gas}}}{(\dot{n}_{\text{gas}} + \dot{n}_{\text{H}_2\text{O}})^2}$$

Eq. 1065.750-6

$$U_{x_{\text{H}_2\text{O}}} = \sqrt{\left(\frac{\partial x_{\text{H}_2\text{O}}}{\partial \dot{n}_{\text{gas}}} \cdot U_{\dot{n}_{\text{gas}}}\right)^2 + \left(\frac{\partial x_{\text{H}_2\text{O}}}{\partial \dot{n}_{\text{H}_2\text{O}}} \cdot U_{\dot{n}_{\text{H}_2\text{O}}}\right)^2}$$

Eq. 1065.750-7

Where:

$\dot{n}_{\text{gas}}$  ≡ molar flow of gas entering the humidity generator.

$U_{\dot{n}_{\text{gas}}}$  ≡ expanded uncertainty (k=2) of the molar flow of gas entering the humidity generator.

$\dot{n}_{\text{H}_2\text{O}}$  ≡ molar flow of H<sub>2</sub>O entering the humidity generator, mol/s.

$U_{\dot{n}_{\text{H}_2\text{O}}}$  ≡ expanded uncertainty (k=2) of the molar flow of H<sub>2</sub>O entering the humidity generator.

$\frac{\partial x_{\text{H}_2\text{O}}}{\partial \dot{n}_{\text{gas}}}$  ≡ partial derivative of  $x_{\text{H}_2\text{O}}$  with respect to  $\dot{n}_{\text{gas}}$ .

$\frac{\partial x_{\text{H}_2\text{O}}}{\partial \dot{n}_{\text{H}_2\text{O}}}$  ≡ partial derivative of  $x_{\text{H}_2\text{O}}$  with respect to  $\dot{n}_{\text{H}_2\text{O}}$ .

$x_{\text{H}_2\text{O}}$  ≡ amount of H<sub>2</sub>O in the calibration gas.

$U_{x_{\text{H}_2\text{O}}}$  ≡ expanded uncertainty (k=2) of the amount of H<sub>2</sub>O in the generated calibration gas.

(C) The following example is a solution for  $U_{x_{H_2O}}$  using the equations in paragraph (c)(6)(B) of this section:

$$\dot{n}_{H_2O} = 0.00138771 \text{ mol/s}$$

$$U_{\dot{n}_{gas}} = 0.000226137 \text{ mol/s}$$

$$\dot{n}_{gas} = 0.0148680 \text{ mol/s}$$

$$U_{\dot{n}_{H_2O}} = 0.0000207436 \text{ mol/s}$$

$$x_{H_2O} = \frac{0.00138771}{0.0148680 + 0.00138771}$$

$$x_{H_2O} = 0.0853676 \text{ mol/mol}$$

$$\frac{\partial x_{H_2O}}{\partial \dot{n}_{gas}} = -1 \cdot \frac{0.00138771}{(0.0148680 + 0.00138771)^2}$$

$$\frac{\partial x_{H_2O}}{\partial \dot{n}_{gas}} = -5.25155 \text{ (mol/mol)/(mol/s)}$$

$$\frac{\partial x_{H_2O}}{\partial \dot{n}_{H_2O}} = \frac{0.0148680}{(0.0148680 + 0.00138771)^2}$$

$$\frac{\partial x_{H_2O}}{\partial \dot{n}_{H_2O}} = 56.2653 \text{ (mol/mol)/(mol/s)}$$

$$U_{x_{H_2O}} = \sqrt{(-5.25155 \cdot 0.000226137)^2 + (56.2653 \cdot 0.0000207436)^2}$$

$$U_{x_{H_2O}} = 0.00166510 \text{ mol/mol}$$

\* \* \* \* \*

### **Subpart K—Definitions and Other Reference Information**

127. Amend § 1065.1001 by:

- a. Adding definitions of “Carbon-containing fuel”, “Lean-burn engine”, and “Neat” in alphabetical order.
- b. Revising the definition for “Rechargeable Energy Storage System (RESS)”.

The additions and revisions read as follows:

#### **§ 1065.1001 Definitions.**

\* \* \* \* \*

Carbon-containing fuel means an engine fuel that is characterized by compounds containing carbon. For example, gasoline, diesel, alcohol, liquefied petroleum gas, and natural gas are carbon-containing fuels.

\* \* \* \* \*

Lean-burn engine means an engine with a nominal air fuel ratio substantially leaner than stoichiometric. For example, diesel-fueled engines are typically lean-burn engines, and gasoline-fueled engines are lean-burn engines if they have an air-to-fuel mass ratio above 14.7:1.

\* \* \* \* \*

Neat means fuel that is free from mixture or dilution with other fuels. For example, hydrogen or natural gas fuel used without diesel pilot fuel are neat.

\* \* \* \* \*

Rechargeable Energy Storage System (RESS) means engine or equipment ~~the~~ components of a hybrid engine or vehicle that store recovered energy for later use to propel the vehicle or accomplish a different primary function. Examples of RESS include the battery system or a hydraulic accumulator, ~~such as the battery system~~ in a hybrid electric vehicle.

\* \* \* \* \*

128. Amend § 1065.1005 by revising the entry for  $M_{NMNEHC}$  in Table 7 of paragraph (f)(2) to read as follows:

**§ 1065.1005 Symbols, abbreviations, acronyms, and units of measure.**

\* \* \* \* \*

(f) \* \* \*

(2) \* \* \*

TABLE 7 OF § 1065.1005—MOLAR MASSES

Symbol	Quantity	g/mol ( $10^{-3} \cdot \text{kg} \cdot \text{mol}^{-1}$ )
* * * * *		
$M_{NMNEHC}$	effective $C_1$ molar mass of nonmethane <del>nonethane</del> hydrocarbon <sup>b</sup>	13.875389
* * * * *		

\* \* \* \* \*

129. Amend § 1065.1010 by revising paragraphs (b)(40) and (f)(2) to read as follows:

**§ 1065.1010 Incorporation by reference.**

\* \* \* \* \*

(b) \* \* \*

(40) ASTM D6348-12<sup>e1</sup>, Standard Test Method for Determination of Gaseous Compounds by Extractive Direct Interface Fourier Transform Infrared (FTIR) Spectroscopy, approved February 1, 2012 (“ASTM D6348”), IBR approved for §§ 1065.257(a), 1065.266(b) and 1065.275(b).

\* \* \* \* \*

(f) \* \* \*

(2) NIST Technical Note 1297, 1994 Edition, Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, IBR approved for §§ 1065.365(g), 1065.750(a)(6) and 1065.1001.

**PART 1074—PREEMPTION OF STATE STANDARDS AND PROCEDURES FOR  
WAIVER OF FEDERAL PREEMPTION FOR NONROAD ENGINES AND NONROAD  
VEHICLES**

130. The authority citation for part 1074 continues to read as follows:  
Authority: 42 U.S.C. 7401-7671q.

131. Amend § 1074.10 by revising paragraph (b) and adding paragraph (c) to read as follows:

**§ 1074.10 Scope of preemption.**

\* \* \* \* \*

(b) States and localities are preempted from adopting or enforcing standards or other requirements relating to the control of emissions from new locomotives and new engines used in locomotives.

(bc) For nonroad engines or vehicles other than those described in paragraph (a) and (b) of this section ~~and § 1074.12~~, States and localities are preempted from enforcing any standards or other requirements relating to control of emissions from nonroad engines or vehicles except as provided in subpart B of this part.

**§ 1074.12—[Removed]**

132. Remove § 1074.12.

~~**§ 1074.12 Scope of preemption-specific provisions for locomotives and locomotive engines**~~

~~(a) States and localities are preempted from adopting or enforcing standards or other requirements relating to the control of emissions from new locomotives and new engines used in locomotives.~~

~~(b) During a period equivalent in length to 133 percent of the useful life, expressed as MW-hrs (or miles where applicable), beginning at the point at which the locomotive or engine becomes new, those standards or other requirements which are preempted include, but are not limited to, the following: emission standards, mandatory fleet average standards, certification requirements, retrofit and aftermarket equipment requirements, and nonfederal in-use testing requirements. The standards and other requirements specified in the preceding sentence are preempted whether applicable to new or other locomotives or locomotive engines.~~

133. Amend § 1074.101 by revising paragraph (a) to read as follows:

**§ 1074.101 Procedures for California nonroad authorization requests.**

(a) California must request authorization from the Administrator to enforce its adopted standards and other requirements relating to control of emissions from nonroad engines or vehicles that are not preempted by § 1074.10(a) or (b) ~~§ 1074.12~~. The request must include the record on which the state rulemaking was based.

\* \* \* \* \*