fuel in front of a DOC, this methodology should also be used during bench aging.

(7) If part of the system is at a lower temperature during regeneration because it is upstream of the temperature generating component, the set the target temperature for the aftertreatment system inlet to be equivalent to the system inlet temperature used during the highest duration non-regeneration mode, or 350 °C, whichever is lower.

(e) *Heat load calculation and tuning for systems that have regeneration events.* Perform this procedure after the preliminary cycles are completed for both normal and regeneration operation. The target cumulative deactivation is determined from the input field data, and then a similar calculation is performed for the preliminary aging cycle. If the cumulative deactivation for the preliminary cycle does not match cumulative deactivation from the field data, then the cycle is tuned over a series of steps until the target is matched.

(1) The deactivation for a given catalyst is calculated for each time step as follows:

$$D_i = e^{\left(\left(\frac{E_a}{R}\right)\cdot\left(\frac{1}{T_{std}} - \frac{1}{T+273.15}\right)\right)}$$

Eq. 1065.1139-7

Where:

D_i = incremental deactivation for time step i.

E_a = thermal reactivity coefficient for the catalyst as determined in §1065.1137.

R = molar gas constant in kJ/mol·K.

T_{std} = standard temperature = 293.15 K.

T = catalyst temperature in K.

(2) Calculate the cumulative deactivation, D_t, for a given catalyst over a series of time steps, N, using the following equation:

$$D_t = \sum_{i=0}^{N} D_i$$

Eq. 1065.1139-8

Where:

i = an indexing variable that represents one time step.

N = total number of cumulative deactivation time steps in the data set.

D_i = incremental deactivation for each time step.

(3) Calculate the cumulative deactivation, D_t, for the input field data set. The time step for the calculations should be 1 second for 1-Hz input data.

(i) First calculate D_t for the non-regeneration portion of the field data set. For Method 2 use the 1-Hz data from the regulatory cycles as the field data set.

(ii) Divide the calculate field D_t by the number of hours represented in the field data set.

(iii) Multiply the hourly D_t by the number of hours required to reach full useful life. This is the target $D_{t,field\text{-}normi}$.

(iv) Multiply the total number of regenerations for full useful life by the cumulative deactivation D_t for the target regeneration profile determined in paragraph (d)(4) of this section. This is the target $D_{t,field\text{-}regen}$.

(v) The total target cumulative deactivation for the field data, $D_{t,field}$, is the sum of $D_{t,field\text{-}normi}$ and $D_{t,field\text{-}regen}$.

(4) Calculate the cumulative deactivation for the candidate aging cycle generated under paragraphs (c) and (d) of this section as follows:

(i) Using the modes and mode durations for normal operation generated in paragraph (c) of this section, calculate the cumulative deactivation, $D_{t,cycle\text{-}norm}$, using the method given in paragraph (e)(2) of this section.

(ii) The total cumulative deactivation for the candidate aging cycle, D_t, is the sum of $D_{t,cycle\text{-}norm}$ and $D_{t,field\text{-}regen}$.

(5) If $D_{t,cycle}$ is within ±1% of $D_{t,field}$, the candidate cycle is deemed representative and may be used for aging.

(6) If $D_{t,cycle}$ is not within ±1% of $D_{t,field}$, the candidate cycle must be adjusted to meet this criterion using the following steps. It should be noted that if the $D_{t,cycle}$ is outside of the criteria it will usually be lower than the $D_{t,field}$.

(i) Increase the duration of the stable portion of the regeneration profile, which is defined as the portion of the regeneration profile where the temperature has completed ramping and is being controlled to a stationary target temperature. Note that this will increase the number of hours of regeneration time. You must compensate for this by decreasing the total number of normal operation (non-regeneration) hours in the cycle. Recalculate the duration of all the normal operation modes. You may not increase the duration of the stable portion of the regeneration profile by more than a factor of 2. If you reach this limit and you still do not meet the criteria in paragraph (e)(5) of this section, proceed to the next step.

(ii) Increase the target temperature of the stable portion of the regeneration profile by the amount necessary to reach the target criteria. You may not increase this temperature higher than the temperature observed in the regeneration profile with the highest D_t observed in the field. If you reach this limit and you still do not meet the criteria in paragraph (e)(5) of this section, proceed to the next step.

(iii) Increase the target temperature of the highest temperature normal operation mode. You may not increase this temperature above the 90th percentile determined in paragraph (b)(1)(v) of this section for Method 1, or above the maximum temperature for the regulatory cycle from which the mode was derived for Method 2. If you reach this limit and you still do not meet the criteria in paragraph (e)(5) of this section, you may repeat this step using the next highest temperature mode, until you reach the target, or all modes have been adjusted.

(iv) If you are unable to reach the target deactivation by following paragraphs (e)(6)(i) through (iii) of this section, use good engineering judgment to increase the number of regenerations to meet the criteria in paragraph (e)(5) of this section. Note that this will increase the total regeneration hours, therefore you must decrease the number of normal operation hours and recalculate mode durations for the normal operation modes.

(v) If you are not able to achieve the target $D_{t,field}$ using the steps in paragraphs (e)(6)(i) through (iv) of this section without exceeding catalyst temperature limits, use good engineering judgement to reduce the acceleration factor from 10 to a lower number. If you reduce the acceleration factor you must re-calculate the number of hours determine in paragraph (a) of this section and re-run the process in this paragraph (e). Note that if you reduce the acceleration factor you must use the same lower acceleration factor in the chemical exposure calculations in paragraph (h) of this section, instead of 10.

(f) *Heat load calculation and tuning for systems that do not have regeneration events*. Follow the steps described for systems with regeneration events to calculate $D_{t,field}$ and $D_{t,cycle}$, omitting the steps related to regeneration events. The $D_{t,cycle}$ will be well below the $D_{t,field}$. Follow the steps given below to adjust the cycle until you meet the criteria in paragraph (e)(5) of this section.

(1) Increase the temperature of the highest temperature mode. Use good engineering judgment to ensure that this temperature does not exceed the limits of the catalyst in a way that might cause rapid deactivation or failure via a mechanism that is not considered normal degradation.

(2) Increase the duration of the highest temperature mode and decrease the duration of the other modes in proportion. You may not increase the duration highest temperature mode by more than a factor of 2.

(3) If you are not able to achieve the target $D_{t,field}$ using the steps in paragraphs (f)(1) and (2) of this section

without exceeding catalyst temperature limits, use good engineering judgement to reduce the acceleration factor from 10 to a lower number. If you reduce the acceleration factor you must re-calculate the number of hours determine in paragraph (a) of this section and re-run the process in this paragraph (f). Note that if you reduce the acceleration factor you must use the same lower acceleration factor in the chemical exposure calculations in paragraph (h) of this section, instead of 10.

(g) *Final aging cycle assembly.* The final step of aging cycle development is the assembly of the actual cycle based on the mode data from either paragraph (e) of this section for systems with infrequent regeneration, or paragraph (f) of this section for systems that do not incorporate infrequent regeneration. This cycle will repeat a number of times until the total target aging duration has been reached.

(1) *Cycle assembly with infrequent regenerations.* For systems that use infrequent regenerations, the number of cycle repeats is equal to the number of regeneration events that happen over full useful life. The total cycle duration of the aging cycle is calculated as the total aging duration in hours divided by the number of infrequent regeneration events. In the case of systems with multiple types of infrequent regenerations, use the regeneration with the lowest frequency to calculate the cycle duration.

(i) If you have multiple types of infrequent regenerations, arrange the more frequent regenerations such that they are spaced evenly throughout the cycle.

(ii) Determine the length of the normal (non-regeneration) part of the cycle by subtracting the regeneration duration, including any regeneration extension determined as part of cycle tuning from paragraph (e) of this section, from the total cycle duration. If you have multiple types of regeneration, then the combined total duration of regeneration events performed in the cycle must be subtracted from the total. For example, if you have one type of regeneration that is performed for 30 minutes every 30 cycle hours, and a second type that is performed for 30 minutes every 10 cycle hours (such that 3 of these secondary events will happen during each cycle), then you would subtract a total of 2 hours of regeneration time from the total cycle duration considering all 4 of these events.

(iii) Divide the duration of the normal part of the cycle into modes based on the final weighting factors determined in paragraph (c) of this section following any mode consolidation.

(iv) Place the mode with the lowest temperature first, then move to the highest temperature mode, followed by the next lowest temperature mode, and then the next highest mode, continuing in this alternating pattern until all modes are included.

(v) Transition between normal modes within (60 to 300) seconds. The transition period is considered complete when you are within ±5 °C of the target temperature for the primary key component. Transitions may follow any pattern of flow and temperature to reach this target within the required 300 seconds.

(vi) For normal modes longer than 30 minutes, you may count the transition time as time in mode. Account for the transition time for modes shorter than 30 minutes by shortening the duration of the longest mode by an equivalent amount of time.

(vii) If the shortest normal operating mode is longer than 60 minutes, you must divide the normal cycle into shorter sub-cycles with the same pattern in paragraph (g)(1)(iii) of this section, but with shorter durations, so that the pattern repeats two or more times. You must divide the cycle into sub-cycles until the duration of the shortest mode in each sub-cycle is no longer than 30 minutes. No mode may have a duration shorter than 15 minutes, not including transition time.

(viii) If a regeneration event is scheduled to occur during a normal mode, shift the start of regeneration to the end of the nearest normal mode.

(2) *Cycle assembly without infrequent regenerations.* For systems that do not use infrequent regenerations, the cycle will be arranged to achieve as much thermal cycling as possible using the following steps.

(i) Assign a duration of 15 minutes to the mode with the lowest weight factor. Calculate the duration of the remaining modes in proportion to the final weight factors after mode durations have been adjusted during heat load tuning in paragraph (f) of this section.

(ii) Place the mode with the lowest temperature first, then move to the highest temperature mode, followed by the next lowest temperature mode, and then the next highest mode, continuing in this alternating pattern until all modes are included.

(iii) Transition between normal modes within (60 to 300) seconds. The transition period is considered complete when you are within ±5 °C of the target temperature for the primary key component. Transitions may follow any pattern of flow and temperature to reach this target within the required 300 seconds.

(iv) For normal modes longer than 30 minutes, you may count the transition time as time in mode. Account for the transition time for modes shorter than 30 minutes by shortening the duration of the longest mode by an equivalent amount of time.

(v) This cycle will be repeated the number of times necessary to reach the target aging duration.

(h) *Chemical exposure targets.* Determine targets for accelerated oil and fuel sulfur exposure as follows:

(1) *Oil exposure targets.* The target oil exposure rate during accelerated aging is 10 times the field average oil consumption rate determined in §1065.1133(a)(2). You must achieve this target exposure rate on a cycle average basis during aging. Use good engineering judgment to determine the oil exposure rates for individual operating modes that will achieve this cycle average target. For engine-based aging stands you will likely have different oil consumption rates for different modes depending on the speed and load conditions you set. For burner-based aging stands, you may find that you have to limit oil exposure rates at low exhaust flow or low temperature modes to ensure good atomization of injected oil. On a cycle average basis, the portion of oil exposure from the volatile introduction pathway (*i.e.*, oil doped in the burner or engine fuel) must be between (10 to 30) % of the total. The remainder of oil exposure must be introduced through bulk pathway.

(2) *Fuel sulfur exposure targets.* The target sulfur exposure rate for fuel-related sulfur is determined by utilizing the field mean fuel rate data for the engine determined in §1065.1133(a)(3). Calculate the total sulfur exposure mass using this mean fuel rate, the total number of non-accelerated hours to reach full useful life, and a fuel sulfur level of 10 ppmw.

(i) For an engine-based aging stand, if you perform accelerated sulfur exposure by additizing engine fuel to a higher sulfur level, determine the accelerated aging target additized fuel sulfur mass fraction, $w_{S,}$ as follows:

$$w_{\mathrm{S,target}} = \frac{\bar{\dot{m}}_{\mathrm{fuel,field}}}{\bar{\dot{m}}_{\mathrm{fuel,cyle}}} \cdot m_{\mathrm{Sfuel,ref}} \cdot S_{\mathrm{acc,rate}}$$

Eq. 1065.1139–9

Where:

$\bar{\dot{m}}_{\mathrm{fuel,field}}$ = field mean fuel flow rate.

$\bar{\dot{m}}_{\mathrm{fuel,cycle}}$ = accelerated aging cylce mean fuel low rate.

$m_{\mathrm{Sfuel,ref}}$ = reference mass of sulfur per mass of fuel = 0.00001 kg/kg.

$S_{\mathrm{acc,rate}}$ = sulfur acceleration rate = 10.

Example:

$\bar{\dot{m}}_{\mathrm{fuel,field}}$= 54.3 kg/hr

$\bar{\dot{m}}_{\mathrm{fuel,cycle}}$ = 34.1 kg/hr

$m_{\mathrm{Sfuel,ref}}$ = 0.00001 kg/kg.

$S_{\mathrm{acc,rate}}$ = 10

$$w_{\mathrm{S,target}} = \frac{54.3}{34.1} \cdot 0.00001 \cdot 10$$

$$w_{\mathrm{S,target}} = 0.000159$$

(ii) If you use gaseous SO_2 to perform accelerated sulfur exposure, such as on a burner-based stand, calculate the target SO_2 concentration to be introduced, $x_{\mathrm{SO2,target}}$, as follows:

$$x_{\mathrm{SO2,target}} = \frac{\bar{\dot{m}}_{\mathrm{fuel,field}}}{\bar{\dot{m}}_{\mathrm{exhaust,cycle}}} \cdot \left(\frac{x_{\mathrm{Sfuel,ref}} \cdot S_{\mathrm{acc,rate}} \cdot M_{\mathrm{exh}}}{M_{\mathrm{S}}}\right)$$

Eq. 1065.1139–10

Where:

$\bar{\dot{m}}_{\mathrm{fuel,field}}$ = field mean fuel flow rate.

$\bar{\dot{m}}_{\mathrm{exhaust,cycle}}$ = mean exhaust flow rate during the burner aging cycle.

$x_{\mathrm{Sfuel,ref}}$ = reference mol fraction of sulfur in fuel = 10 μmol/mol.

$S_{\mathrm{acc,rate}}$ = sulfur acceleration rate = 10.

M_{exh} = molar mass of exhaust = molar mass of air.

M_{S} = molar mass of sulfur.

Example:

$\bar{\dot{m}}_{\mathrm{fuel,field}}$= 54.3 kg/hr

$\bar{\dot{m}}_{\mathrm{exhaust,cycle}}$= 1000.8 kg/hr

$x_{\mathrm{Sfuel,ref}}$ = 10 μmol/mol

$S_{\mathrm{acc,rate}}$ = 10

M_{exh} = 28.96559 g/mol

M_{S} = 32.065 g/mol

$$x_{\mathrm{SO2,target}} = \frac{54.3}{1000.8} \cdot \left(\frac{10 \cdot 10 \cdot 28.96559}{32.065}\right)$$

$$x_{\mathrm{SO2,target}} = 4.90\ \mu\mathrm{mol/mol}$$

(iii) You may choose to turn off gaseous sulfur injection during infrequent regeneration modes, but if you do you must increase the target SO_2 concentration by the ratio of total aging time to total normal (non-regeneration) aging time.

[79 FR 23820, Apr. 28, 2014, as amended at 89 FR 29829, Apr. 22, 2024]

§ 1065.1141 Facility requirements for engine-based aging stands.

An engine-based accelerated aging platform is built around the use of a compression-ignition engine for generation of heat and flow. You are not required to use the same engine as the target application that is being aged. You may use any compression-ignition engine as a bench aging engine, and the engine may be modified as needed to support meeting the aging procedure requirements. You may use the same bench aging engine for deterioration factor determination from multiple engine families. The engine must be capable of reaching the combination of temperature, flow, NO_X, and oil consumption targets required. We recommend using an engine platform larger than the target application for a given aftertreatment system to provide more flexibility to achieve the target conditions and oil consumption rates. You may modify the bench aging engine controls in any manner necessary to help reach aging conditions. You may bypass some of the bench aging engine exhaust around the aftertreatment system being aged to reach targets, but you must account for this in all calculations and monitoring to ensure that the correct amount of oil and sulfur are reaching the aftertreatment system. If you bypass some of the engine exhaust around the aftertreatment system, you must directly measure exhaust flow rate through the aftertreatment system. You may dilute bench aging engine exhaust prior to introduction to the aftertreatment system, but you must account for this in all calculations and monitoring to ensure that the correct engine conditions and the correct amount of oil and sulfur are reaching the aftertreatment system. Your engine-based aging stand must incorporate the following capabilities:

(a) Use good engineering judgment to incorporate a means of controlling temperature independent of the engine. An example of such a temperature control would be an air-to-air heat exchanger. The temperature control system must be designed to prevent condensation in the exhaust upstream of the aftertreatment system. This independent temperature control is necessary to provide the flexibility required to reach temperature, flow, oil consumption targets, and NO_X targets.

(b) Use good engineering judgment to modify the engine to increase oil consumption rates to levels required for accelerated aging. These increased oil consumption levels must be sufficient to reach the bulk pathway exposure targets determined in §1065.1139(h). A combination of engine modifications and careful operating mode selection will be used to reach the final bulk pathway oil exposure target on a cycle average. You must modify the engine in a fashion that will increase oil consumption in a manner such that the oil consumption is still generally representative of oil passing the piston rings into the cylinder. Use good engineering judgment to break in the modified engine to stabilize oil consumption rates. We recommend the following methods of modification (in order of preference):

(1) Install the second compression ring inverted (upside down) on one or more of the cylinders of the bench aging engine. This is most effective on rings that feature a sloped design to promote oil control when normally installed.

(2) If the approach in paragraph (b)(1) of this section is insufficient to reach the targets, modify the oil control rings in one or more cylinders to reduce the spring tension on the oil control ring. It should be noted that this is likely to be an iterative process until the correct modification has been determined.

(3) If the approach in paragraph (b)(2) of this section is insufficient to reach the targets, modify the oil control rings in one or more cylinders to create small notches or gaps (usually no more than 2 per cylinder) in the top portion of the oil control rings that contact the cylinder liner (care must be taken to avoid compromising the structural integrity of the ring itself).

(c) We recommend that the engine-aging stand include a constant volume oil system with a sufficiently large oil reservoir to avoid oil ‘‘top-offs’’ between oil change intervals.

(d) If the engine-aging stand will be used for aging of systems that perform infrequent regenerations, the aging stand must incorporate a means of increasing temperature representative of the target application. For example, if the target application increases temperature for regeneration by introducing fuel into the exhaust upstream of an oxidation catalyst, the aging stand must incorporate a similar method of introducing fuel into the exhaust.

(e) If the engine-aging stand will be used for aging systems that incorporate SCR-based NO_X reduction, the aging stand must incorporate a representative means of introducing DEF at the appropriate location(s).

(f) Use good engineering judgment to incorporate a means of monitoring oil consumption on a periodic basis. You may use a periodic drain and weigh approach to quantify oil consumption. We recommend that you incorporate a method of continuous oil consumption monitoring, but you must validate that method with periodic draining and weighing of the engine oil. You must validate that the aging stand reaches oil consumption targets prior to the start of aging. You must verify oil consumption during aging prior to each emission testing point, and at each oil change interval. Validate or verify oil consumption over a running period of at least 72 hours to obtain a valid measurement. If you do not include the constant volume oil system recommended in paragraph (c) of this section, you must account for all oil additions.

(g) Use good engineering judgment to establish an oil change interval that allows you to maintain relatively stable oil consumption rates over the aging process. Note that this interval may be shorter than the normal recommended interval for the engine due to the modifications that have been made.

(h) If the engine-aging stand will be used for aging of systems that incorporate a diesel particulate filter (DPF), we recommend you perform secondary tracking of oil exposure by using clean (soot free) DPF weights to track ash loading and compare this mass of ash to the amount predicted using the measured oil consumption mass and the oil ash concentration. The mass of ash found by DPF weight should fall within (55 to 70)% of the of mass predicted from oil consumption measurements.

(i) Incorporate a means of introducing lubricating oil into the engine fuel to enable the volatile pathway of oil exposure. You must introduce sufficient oil to reach the volatile pathway oil exposure targets determined in paragraph (h) of this section. You must measure the rate of volatile pathway oil introduction on a continuous basis.

(j) If you perform sulfur acceleration by increasing the sulfur level of the engine fuel, you must meet the target sulfur level within ±5 ppmw. Verify the sulfur level of the fuel prior to starting aging, or whenever a new batch of aging fuel is acquired.

(k) If you use gaseous SO_2 for sulfur acceleration, you must incorporate a means to introduce the gaseous SO_2 upstream of the aftertreatment system. Use good engineering judgment to ensure that gaseous SO_2 is well mixed prior to entering the aftertreatment system. You must monitor the rate of gaseous SO_2 introduction on a continuous basis.

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§ 1065.1143 Requirements for burner-based aging stands.

A burner-based aging platform is built using a fuel-fired burner as the primary heat generation mechanism. The burner must utilize diesel fuel and it must produce a lean exhaust gas mixture. You must configure the burner system to be capable of controlling temperature, exhaust flow rate, NO_X, oxygen, and water to produce a representative exhaust mixture that meets the accelerated aging cycle targets for the aftertreatment system to be aged. You may bypass some of the bench aging exhaust around the aftertreatment system being aged to reach targets, but you must account for this in all calculations and monitoring to ensure that the correct amount of oil and sulfur are reaching the aftertreatment system. The burner system must incorporate the following capabilities:

(a) Directly measure the exhaust flow through the aftertreatment system being aged.

(b) Ensure transient response of the system is sufficient to meet the cycle transition time targets for all parameters.

(c) Incorporate a means of oxygen and water control such that the burner system is able to generate oxygen and water levels representative of compression-ignition engine exhaust.

(d) Incorporate a means of oil introduction for the bulk pathway. You must implement a method that introduces lubricating oil in a region of the burner that does not result in complete combustion of the oil, but at the same time is hot enough to oxidize oil and oil additives in a manner similar to what occurs when oil enters the cylinder of an engine past the piston rings. Care must be taken to ensure the oil is properly atomized and mixed into the post-combustion burner gases before they have cooled to normal exhaust temperatures, to insure proper digestion and oxidation of the oil constituents. You must measure the bulk pathway oil injection rate on a continuous basis. You must validate that this method produces representative oil products using the secondary method in § 1065.1141(h) regardless of whether you will use the burner-based aging stand to age systems which include a DPF. Use good engineering judgment to select a DPF for the initial validation of the system. Perform this validation when the burner-based aging stand is first commissioned or if any system modifications are made that affect the oil consumption introduction method. We also recommend that you examine ash distribution on the validation DPF in comparison to a representative engine aged DPF.

(e) Incorporate a means of introducing lubricating oil into the burner fuel to enable the volatile pathway of oil exposure. You must introduce sufficient oil to reach the volatile pathway oil exposure targets determined in §1065.1139(h). You must measure the rate of volatile pathway oil introduction on a continuous basis.

(f) If the burner-based aging stand will be used for aging of systems that perform infrequent regenerations, the aging stand must incorporate a means of increasing temperature representative of the target application. For example, if the target application increases temperature for regeneration by introducing fuel into the exhaust upstream of an oxidation catalyst, the aging stand must incorporate a similar method of introducing fuel into the exhaust.

(g) If the burner-based aging stand will be used for aging of systems that incorporate SCR-based NO_X reduction, the aging stand must incorporate a representative means of introducing DEF at the appropriate location(s).

(h) If the burner-based aging stand will be used for aging of systems that incorporate a diesel particulate filter (DPF), we recommend you perform secondary tracking of oil exposure by using clean (soot free) DPF weights to track ash loading and compare this mass of ash to the amount predicted using the measured oil consumption mass and the oil ash concentration. The mass of ash found by DPF weight should fall within (55 to 70)% of the of mass predicted from oil consumption measurements.

(i) You must incorporate a means to introduce the gaseous SO_2 upstream of the aftertreatment system. Use good engineering judgment to ensure that gaseous SO_2 is well mixed prior to entering the aftertreatment system. You must monitor the rate of gaseous SO_2 introduction on a continuous basis.

§ 1065.1145 Execution of accelerated aging, cycle tracking, and cycle validation criteria.

The aging cycle generally consists first of practice runs to validate and tune the final cycle, followed by the actual running of the repeat cycles needed to accumulate field equivalent hours to reach full useful life. During the course of the aging run, various aging parameters are tracked to allow verification of proper cycle execution, as well as to allow for correction of the aging parameters to stay within the target limits.

(a) *Preliminary cycle validation runs.* Prior to the start of aging, conduct a number of practice runs to tune the cycle parameters. It is recommended that initial practice runs be conducted without the aftertreatment installed, but with the backpressure of the aftertreatment simulated to help ensure that the tuned cycle is representative. For final cycle tuning, including regenerations, it is recommended to use a duplicate or spare aftertreatment system of similar design to the target system, to avoid damage or excessive initial aging during the tuning. However, it is permissible to conduct final tuning using the target system being aged, but you must limit the total duration to no more than 100 field equivalent hours (10 hours of accelerated aging), including both thermal and chemical components. The process followed for these initial runs will vary depending on whether you are using an engine-based platform or a burner-based platform.

(1) *Engine-based platform.* (i) *Initial cycle development.* It will be necessary to determine a set of engine modes that will generate the required combinations of temperature, exhaust flow, oil consumption, and NO_X to meet the target aging requirements. The development of these modes will be an iterative process using the engine and independent temperature control features of the aging stand. This process assumes that you have already implemented the oil consumption increase

modifications, and that these have already been stabilized and validated to reach the necessary levels of bulk oil exposure. In general, we recommend the use of higher engine speeds and loads to generate the desired oil consumption, leveraging the temperature controls as needed to lower temperature to the targets. Several iterations will likely be needed to reach all targets. Note that during transitions you may utilize any combination of conditions necessary to help primary component catalysts reach the target temperature and flow conditions within no more than 5 minutes. For example, you may use a higher exhaust flow rate and lower temperature to rapidly cool the aftertreatment system to the next temperature. NO_X targets do not need to be met during transitions. It is permissible to deviate from engine-out NO_X emission targets if needed to reach the temperature, exhaust flow, and oil consumption targets. We recommend that you maintain a NO_X level that is at the target level or higher, but you may lower NO_X by up to 25%, if necessary, on some modes. Note that validation of oil consumption requires at least 72 hours of operation. Tune the parameters for infrequent regeneration towards then end of this initial development process (such as hydrocarbon injection schedules and temperature ramp rates).

(ii) *Final cycle validation.* Once the cycle is tuned, conduct a final run using the target aftertreatment system to verify conditions and log temperatures for heat load calculation. Using the recorded cycle data, calculate D_t for all primary component catalysts to ensure that you are matching the desired $D_{t,cycle}$ targets. If you are not within ±3% of the target $D_{t,cycle,}$ adjust the cycle accordingly. Calculate D_t for any secondary catalyst components to verify that they are within ±3% of either the target D_t or the target aging metric. Note that the accelerated aging methodology assumes that the relationship between the temperature of the primary and secondary catalyst components will the be same as the field observations. If this relationship deviates in the lab by having more or less heat transfer through the system, it may be necessary to modify that relationship on the aging stand. You may need to take measures such as adding or removing insulation or utilize external cooling fans to help these parameters match more closely.

(2) *Burner-based platform.* (i) *Cycle development.* The burner-based platform will be able to meet the exhaust flow, temperature, NO_X, and oil consumption targets directly without the need for additional cycle development. This process assumes that you have already implemented and validated your oil consumption exposure methods to reach the necessary levels of bulk oil exposure. In addition, you must meet the oxygen and water targets during aging modes within ±2% for oxygen and ±2% for water. Note that during transitions you may utilize any combination of conditions necessary to help primary component catalysts reach the target temperature and flow conditions within no more than 5 minutes. For example, you may use a higher exhaust flow rate and lower temperature to rapidly cool the aftertreatment system to the next temperature. NO_X, oxygen, and water targets do not need to be met during transitions.

(ii) *Final cycle validation.* Once the cycle is tuned, conduct a final run using the target aftertreatment system to verify conditions and log temperatures for heat load calculation. Using the recorded cycle data, calculate D_t for all primary components catalysts to ensure that you are matching the desired $D_{t,cycle}$ targets. If you are not within ±3% of the target $D_{t,cycle,}$ adjust the cycle accordingly. Calculate D_t for any secondary catalyst components to check that they are within ±3% of either the target D_t or the target aging metric. Note that the accelerated aging methodology assumes that the relationship between the temperature of the primary and secondary catalyst components will the be same as that observed in the field. If this relationship deviates in the lab by having more or less heat transfer through the system, it may be necessary to modify that relationship on the aging stand. You may need to take measures such as adding or removing insulation or utilize external cooling fans to help these parameters match more closely.

(b) *Aftertreatment break in.* Break in the emission-data engine and aftertreatment prior to the initial zero-hour test by running both on an engine dynamometer as described in subpart E of this part. Use good engineering judgment to develop a representative cycle that represents the field data. You may use the same data used for accelerated aging cycle development or other data. If your system utilizes infrequent regeneration, include at least one complete regeneration event, but we recommend that you include at least two such events to stabilize emissions performance. Your break in process must include at least 125 hours of engine operation with the aftertreatment system. You may ask to use a longer break in duration based on good engineering judgment, to ensure that emission performance is stabilized prior to the zero-hour testing.

(c) *Initial emission testing.* Prior to the start of accelerated aging conduct the initial zero-hour emission test and any required engine dynamometer aging following the requirements of the standard setting part for your engine. Dynaometer aging hours count toward the total aging hours.

(d) *Accelerated aging.* Following zero-hour emission testing and any engine dynamometer aging, perform accelerated aging using the cycle validated in either paragraph (a)(1) or (2) of this section. Repeat the cycle the number of times required to reach full useful life equivalent aging. Interrupt the aging cycle as needed to conduct any scheduled intermediate emission tests, clean the DPF of accumulated ash, and for any facility-related reasons. We recommended you interrupt aging at the end of a given aging cycle, following the completion of any scheduled infrequent regeneration event. If an aging cycle is paused for any reason, we recommended that you resume the aging cycle at the same point in the cycle where it stopped to ensure consistent thermal and chemical exposure of the aftertreatment system.

(e) *QA tracking and validation.* During aging, track a number of aging parameters to ensure that fall within the required limits. Correct aging parameters as need to remain within the required control limits.

(1) *Thermal load tracking.* For each primary catalyst component, generate a target line which describes the relationship between aging hours on the cycle and cumulative deactivation, D_t. Generate control limit lines that are ±3% of the target line. You must remain within these control limits over the course of aging. Adjust aging parameters as needed to remain within these limits for the primary catalyst components. For each secondary catalyst component, generate both a target D_t line and a line describing the target behavior of the aging metric directly. You must remain within either ±10% of either the D_t line or ±3% of the aging metric target line for any secondary catalyst component. Adjust aging parameters as needed to remain within these limits noting that you must remain within limits for the primary components. Adjusting the secondary catalyst aging may require altering heat transfer through the system to make it more representative of the field aging.

(2) *Oil consumption tracking.* Generate a target oil consumption line for both the bulk and volatile pathway which describes the relationship between oil exposure and aging hours on the cycle. For the engine-based stand the control limits are ±10% for total oil consumption, noting that the volatile pathway must not exceed 30% of the total. For the burner-based stand, the controls limits are ±5% for both pathways, which are tracked separately.

(i) *Changing engine oil.* For an engine-based platform, periodically change engine oil to maintain stable oil consumption rates and maintain the health of the aging engine. Interrupt aging as needed to perform oil changes. Perform a drain-and-weigh measurement. If you see a sudden change in oil consumption it may be necessary to stop aging and either change oil or correct an issue with the accelerated oil consumption. If the aging engine requires repairs to correct an oil consumption issue in the middle of aging, you must re-validate the oil consumption rate for 72 hours before you continue aging. The engine exhaust should be left bypassing the aftertreatment system until the repaired engine has been validated.

(ii) *Secondary oil consumption validation.* If your aftertreatment includes a diesel particulate filter, we recommend that you perform secondary validation of oil consumption by using clean (soot free) DPF weights to track ash loading and compare this mass of ash to the amount predicted using the measured oil consumption mass and the oil ash concentration. The mass of ash found by DPF weight should fall within a range of (55 to 70)% of the of mass predicted from oil consumption measurements. Perform this validation at the end of aging, at any intermediate emission test points, and at any point where you need to clean the DPF of accumulated ash in according with recommended maintenance.

(iii) *Sulfur tracking.* Generate a fuel sulfur exposure line describing the relationship between aging hours and cumulative target sulfur exposure mass. The control limits for sulfur exposure are ±3%. Log actual fuel consumption and the measured fuel sulfur level of the current batch of fuel (if you are doping fuel to accelerate sulfur exposure) for engine stand aging. Use these measurements to ensure that sulfur exposure remains within the control limits. Adjust sulfur doping levels in the fuel from batch to batch as needed to stay within limits. If you use gaseous SO_2 for sulfur acceleration, monitor the mass flow rate of the gaseous sulfur. Use these measurements to calculate total sulfur mass exposure, and correct SO_2 gas flow rates as needed to stay within the control limits.

(f) *Emission testing at intermediate and final test points.* Conduct emission testing at the end of aging and at any intermediate emission test points as described in the standard setting part. Following installation of the aged aftertreatment system on the emission-data engine at intermediate or final test points, prior to the start of emission testing, use good engineering judgment to operate the engine and aftertreatment system for a number of hours to stabilize emission controls and to allow any adaptive controls to update. Declare the number of stabilization hours prior to the start of the accelerated aging program.

[79 FR 23820, Apr. 28, 2014, as amended at 89 FR 29831, Apr. 22, 2024]

PART 1066—VEHICLE-TESTING PROCEDURES

Subpart A—Applicability and General Provisions

Sec.

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

Subpart C—Dynamometer Specifications

AUTHORITY: 42 U.S.C. 7401–7671q.

SOURCE: 79 FR 23823, Apr. 28, 2014, unless otherwise noted.

Subpart A—Applicability and General Provisions

§ 1066.1 Applicability.

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

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

(2) Model year 2022 and later motor vehicles (light-duty and heavy-duty)

that are subject to chassis testing for exhaust emissions under 40 CFR part 86, other than highway motorcycles. See 40 CFR part 86 for provisions describing how to implement this part 1066.

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

(c) The testing in this part 1066 is designed for measuring exhaust, evaporative, and refueling emissions. Procedures for measuring evaporative and refueling emissions for motor vehicles are in some cases integral with exhaust measurement procedures as described in §1066.801. Subpart J of this part describes provisions that are unique to evaporative and refueling emission measurements. Other subparts in this part are written with a primary focus on measurement of exhaust emissions.

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

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

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

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

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

(g) For additional information regarding the test procedures in this part, visit our website at *www.epa.gov*, and in particular *https://www.epa.gov/vehicle-and-fuel-emissions-testing/vehicle-testing-regulations*.

[79 FR 23823, Apr. 28, 2014, as amended at 86 FR 34581, June 29, 2021]

§ 1066.2 Submitting information to EPA under this part.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(8) What requirements apply for evaporative and refueling emissions?

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

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

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

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

TABLE 1 OF § 1066.5—DESCRIPTION OF PART 1066 SUBPARTS

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

§ 1066.10 Other procedures.

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

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

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

[79 FR 23823, Apr. 28, 2014, 80 FR 9120, Feb. 19, 2015]

§ 1066.15 Overview of test procedures.

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

(a) The standard-setting part describes the emission standards that apply. Evaporative and refueling emissions are generally in the form of grams total hydrocarbon equivalent per test. We set exhaust emission standards in g/mile (or g/km), for the following constituents:

(1) Total oxides of nitrogen, NO_X.

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

(i) Total hydrocarbons, THC.

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

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

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

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

(3) Particulate matter, PM.

(4) Carbon monoxide, CO.

(5) Carbon dioxide, CO_2.

(6) Methane, CH_4.

(7) Nitrous oxide, N_2O.

(8) Formaldehyde, CH_2O.

(b) Note that some vehicles may not be subject to standards for all the exhaust emission constituents identified in paragraph (a) of this section. Note also that the standard-setting part may include standards for pollutants not listed in paragraph (a) of this section.

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

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

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

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

(ii) *Batch sampling.* In batch sampling, continuously extract and store a sample of raw or dilute exhaust for later measurement. Extract a sample proportional to the raw or dilute exhaust flow rate, as applicable. You may extract and store a proportional sample of exhaust in an appropriate container, such as a bag, and then measure NO_X, HC, CO, CO_2, CH_4, N_2O, and CH_2O concentrations in the container after the test interval. You may deposit PM from proportionally extracted exhaust onto an appropriate substrate, such as a filter. In this case, divide the PM by the amount of filtered exhaust to calculate the PM concentration. Multiply batch sampled concentrations by the total (raw or dilute) flow from which it was extracted during the test interval. This product is the total mass of the emitted constituent.

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

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

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

(d) Refer to subpart G of this part and the standard-setting part for calculations to determine g/mile emission rates.

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

§ 1066.20 Units of measure and overview of calculations.

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

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

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

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

(3) 1 inch = 25.4 mm.

(4) 1 mile = 1609.344 m.

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

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

(c) *Temperature*. We generally designate temperatures in units of degrees Celsius (°C) unless a calculation requires an absolute temperature. In that case, we designate temperatures in units of Kelvin (K). For conversion purposes throughout this part, 0 °C equals 273.15 K. Unless specified otherwise, always use absolute temperature values for multiplying or dividing by temperature.

(d) *Absolute pressure*. Measure absolute pressure directly or calculate it as the sum of atmospheric pressure plus a differential pressure that is referenced to atmospheric pressure. Always use absolute pressure values for multiplying or dividing by pressure.

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

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

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

(2) Whenever we specify a range by the interval between two values, you may target any associated control

point to any value within that range. An example of this type of range is ''(40 to 50) kPa''.

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

§ 1066.25 Recordkeeping.

(a) The procedures in this part include various requirements to record data or other information. Refer to the standard-setting part and § 1066.695 regarding specific recordkeeping requirements.

(b) You must promptly send us organized, written records in English if we ask for them. We may review them at any time.

(c) We may waive specific reporting or recordkeeping requirements we determine to be unnecessary for the purposes of this part and the standard-setting part. Note that while we will generally keep the records required by this part, we are not obligated to keep records we determine to be unnecessary for us to keep. For example, while we require you to keep records for invalid tests so we may verify that your invalidation was appropriate, it is not necessary for us to keep records for our own invalid tests.

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

§ 1066.101 Overview.

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

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

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

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

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

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

(5) The provisions of 40 CFR part 1065, subpart I, describe specifications for testing with oxygenated fuels; these specifications apply for NMOG determination as described in § 1066.635.

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

§ 1066.105 Ambient controls and vehicle cooling fans.

(a) *Ambient conditions.* Dynamometer testing under this part generally requires that you maintain the test cell within a specified range of ambient temperature and humidity. Use good engineering judgment to maintain relatively uniform temperatures throughout the test cell before testing. You are generally not required to maintain uniform temperatures throughout the test cell while the vehicle is running due to the heat generated by the vehicle. Measured humidity values must represent the conditions to which the vehicle is exposed, which includes intake air; other than the intake air, humidity does not affect emissions, so humidity need not be uniform throughout the test cell.

(b) *General requirements for cooling fans.* Use good engineering judgment to select and configure fans to cool the test vehicle in a way that meets the specifications of paragraph (c) of this section and simulates in-use operation. If you demonstrate that the specified fan configuration is impractical for special vehicle designs, such as vehicles with rear-mounted engines, or it does not provide adequate cooling to properly represent in-use operation, you may ask us to approve increasing fan capacity or using additional fans.

(c) *Allowable cooling fans for vehicles at or below 14,000 pounds GVWR.* Cooling fan specifications for vehicles at or below 14,000 pounds GVWR depend on the test cycle. Paragraph (c)(1) of this section summarizes the cooling fan specifications for the different test cycles; the detailed specifications are described in paragraphs (c)(2) through (5) of this section. See § 1066.410 for instruction regarding how to use the fans during testing.

(1) Cooling fan specifications for different test cycles are summarized as follows:

(i) For the FTP test cycle, the allowable cooling fan configurations are described in paragraphs (c)(2) and (3) of this section.

(ii) For the HFET test cycle, the allowable cooling fan configurations are described in paragraphs (c)(2) and (3) of this section.

(iii) For the US06 test cycle, the allowable cooling fan configurations are described in paragraphs (c)(2) and (4) of this section.

(iv) For the LA–92 test cycle, the allowable cooling fan configurations are described in paragraphs (c)(2) and (4) of this section.

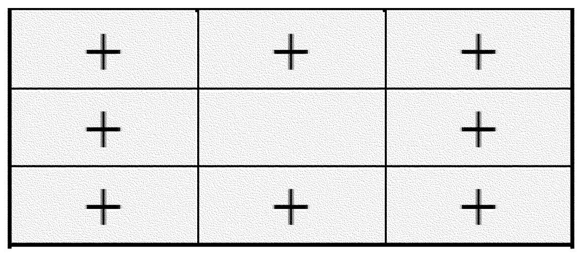
(v) For SC03 and AC17 test cycles, the allowable cooling fan configuration is described in paragraph (c)(5) of this section.

(2) You may use a road-speed modulated fan system meeting the specifications of this paragraph (c)(2) for anything other than SC03 and AC17 testing. Use a road-speed modulated fan that achieves a linear speed of cooling air at the blower outlet that is within ±3.0 mi/hr (±1.3 m/s) of the corresponding roll speed when vehicle speeds are between 5 and 30 mi/hr, and within ±6.5 mi/hr (±2.9 m/s) of the corresponding roll speed at higher vehicle speeds; however you may limit the fan's maximum linear speed to 70 mi/hr. We recommend that the cooling fan have a minimum opening of 0.2 m^2 and a minimum width of 0.8 m.

(i) Verify the air flow velocity for fan speeds corresponding to vehicle speeds of 20 and 40 mi/hr using an instrument that has an accuracy of ±2% of the measured air flow speed.

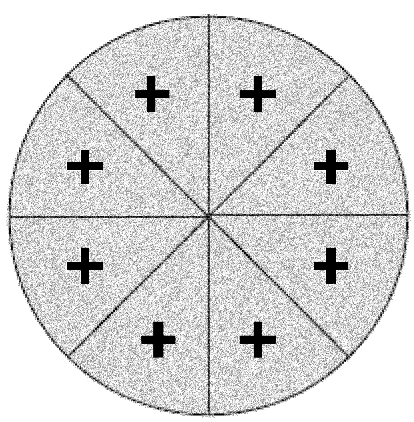
(ii) For fans with rectangular outlets, divide the fan outlet into sections as shown in Figure 1 of this section. As illustrated by the '' + '' in the following figure, measure flow from the center of each section; do not measure the flow from the center section.

Figure 1 of § 1066.105—Rectangular fan outlet grid



(iii) For fans with circular outlets, divide the fan outlet into 8 equal sections as shown in Figure 2 of this section. As illustrated by the " + " in the following figure, measure flow on the radial centerline of each section, at a radius of two-thirds of the fan's total radius.

Figure 2 of § 1066.105—Circular fan outlet grid



(iv) Verify that the uniformity of the fan's axial flow is constant across the discharge area within a tolerance of ±4.0 mi/hr of the vehicle's speed at fan speeds corresponding to 20 mi/hr, and within ±8.0 mi/hr at fan speeds corresponding to 40 mi/hr. For example, at a vehicle speed of 20.2 mi/hr, axial flow at all locations denoted by the "+" across the discharge nozzle must be between 16.2 and 24.2 mi/hr. When measuring the axial air flow velocity, use good engineering judgment to determine the distance from the nozzle outlet at each point of the fan outlet grid. Use these values to calculate a mean air flow velocity across the discharge area at each speed setting. The instrument used to verify the air velocity must have an accuracy of ±2% of the measured air flow velocity.

(v) Use a multi-axis flow meter or another method to verify that the fan's air flow perpendicular to the axial air flow is less than 15% of the axial air flow, consistent with good engineering judgment. Demonstrate this by comparing the perpendicular air flow velocity to the mean air flow velocities determined in paragraph (c)(2)(iv) of this section at vehicle speeds of 20 and 40 mi/hr.

(3) You may use a fixed-speed fan with a maximum capacity up to 2.50 m^3/s for FTP and HFET testing.

(4) You may use a fixed-speed fan with a maximum capacity up to 7.10 m^3/s for US06 and LA–92 testing.

(5) For SC03 and AC17 testing, use a road-speed modulated fan with a minimum discharge area that is equal to or exceeds the vehicle's frontal inlet area. We recommend using a fan with a discharge area of 1.7 m^2.

(i) Air flow volumes must be proportional to vehicle speed. Select a fan size that will produce a flow volume of approximately 45 m^3/s at 60 mi/hr. If this fan is also the only source of test cell air circulation or if fan operational mechanics make the 0 mi/hr air flow requirement impractical, air flow of 2 mi/hr or less at 0 mi/hr vehicle speed is allowed.

(ii) Verify the uniformity of the fan's axial flow as described in paragraph (c)(2)(iv) of this section, except that you must measure the axial air flow velocity 60 cm from the nozzle outlet at each point of the discharge area grid.

(iii) Use a multi-axis flow meter or another method to verify that the fan's air flow perpendicular to the axial air flow is less than 10% of the axial air flow, consistent with good engineering judgment. Demonstrate this by comparing the perpendicular air flow velocity to the mean air flow velocities determined in paragraph (c)(2)(iv) of this section at vehicle speeds of 20 and 40 mi/hr.

(iv) In addition to the road-speed modulated fan, we may approve the use of one or more fixed-speed fans to provide proper cooling to represent in-use operation, but only up to a total of 2.50 m^3/s for all additional fans.

(d) *Allowable cooling fans for vehicles above 14,000 pounds GVWR.* For all testing, use a road-speed modulated fan system that achieves a linear speed of cooling air at the blower outlet that is within ±3.0 mi/hr (±1.3 m/s) of the corresponding roll speed when vehicle speeds are between 5 and 30 mi/hr, and within ±10 mi/hr (±4.5 m/s) of the corresponding roll speed at higher vehicle speeds. For vehicles above 19,500 pounds GVWR, we recommend that the cooling fan have a minimum opening of 2.75 m^2, a minimum flow rate of 60 m^3/s at a fan speed of 50 mi/hr, and a minimum speed profile in the free stream flow, across the duct that is ±15% of the target flow rate.

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74195, Oct. 25, 2016]

§ 1066.110 Equipment specifications for emission sampling systems.

(a) This section specifies equipment related to emission testing, other than measurement instruments. This equipment includes dynamometers (described further in subpart C of this part) and various emission-sampling hardware.

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

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

(i) Minimize lengths of laboratory exhaust tubing. You may use a total length of laboratory exhaust tubing up to 4 m without needing to heat or insulate the tubing. However, you may use a total length of laboratory exhaust tubing up to 10 m, or up to 15 m for samples not involving PM measurement, if you insulate and/or heat the tubing to minimize the temperature difference between the exhaust gas and the whole tubing wall over the course of the emission test. The laboratory exhaust tubing starts at the end of the vehicle's tailpipe and ends at the first sample point or the first dilution point. The laboratory exhaust tubing may include flexible sections, but we recommend that you limit the amount of flexible tubing to the extent practicable. For multiple-tailpipe configurations where the tailpipes combine into a single flow path for emission sampling, the start of the laboratory exhaust tubing may be taken at the last joint where the exhaust flow first becomes a single, combined flow.

(ii) For vehicles above 14,000 pounds GVWR, you may shorten the tailpipe up to the outlet of the last aftertreatment device or silencer, whichever is furthest downstream.

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

(iv) Use laboratory exhaust tubing materials that are smooth-walled and not chemically reactive with exhaust constituents. (For purposes of this paragraph (b)(1), nominally smooth spiral-style and accordion-style flexible tubing are considered to be smooth-walled.) For measurements involving PM, tubing materials must also be electrically conductive. Stainless steel is an acceptable material for any testing. You may use short sections of nonconductive flexible tubing to connect a PM sampling system to the vehicle's tailpipe; use good engineering judgment to limit the amount of nonconductive surface area exposed to the vehicle's exhaust.

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

(vi) You must seal your system to the extent necessary to ensure that any remaining leaks do not affect your ability to demonstrate compliance with the applicable standards in this chapter. We recommend that you seal all known leaks.

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

(viii) For vehicles with multiple tailpipes, route the exhaust into a single flow. To ensure mixing of the multiple exhaust streams before emission sampling, we recommend a minimum Reynolds number, $Re^{\#}$, of 4000 for the combined exhaust stream, where $Re^{\#}$ is based on the inside diameter of the combined flow at the first sampling point. You may configure the exhaust system with turbulence generators, such as orifice plates or fins, to achieve good mixing; this may be necessary for good mixing if $Re^{\#}$ is less than 4000. $Re^{\#}$ is defined in 40 CFR 1065.640.

(2) Use equipment specifications in 40 CFR 1065.140 through 40 CFR 1065.190, except as follows:

(i) For PM background measurement, the following provisions apply in addition to the provisions in 40 CFR 1065.140(b):

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

(B) You may sample background PM from the dilution tunnel at any time before or after an emission test using the same sampling system used during the emission test. For this background sampling, the dilution tunnel blower must be turned on, the vehicle must be disconnected from the laboratory exhaust tubing, and the laboratory exhaust tubing must be capped. You may run this PM blank test in combination with the dilute exhaust flow verification (propane check) in 40 CFR 1065.341, as long as the exhaust tubing inlet to the CVS has a filter meeting the requirements of 40 CFR 1065.140(b)(3).

(C) The duration of your background sample may be different than that of the test cycle in which you are applying the background correction, consistent with good engineering judgment.

(D) Your PM background correction may not exceed 5 μg or 5% of the net PM mass expected at the standard, whichever is greater.

(ii) The provisions of 40 CFR 1065.140(d)(2)(iv) do not apply.

(iii) For PM samples, configure dilution systems using the following limits:

(A) Control the dilution air temperature as described in 40 CFR 1065.140(e)(1), except that the temperature may be set to (15 to 52) °C. Use good engineering judgment to control

PM sample temperature as required under 40 CFR 1065.140(e)(4).

(B) Apply the provisions of this paragraph (b)(2)(iii)(B) instead of 40 CFR 1065.140(e)(2). Add dilution air to the raw exhaust such that the overall dilution factor of diluted exhaust to raw exhaust, as shown in Eq. 1066.610–2 or 1066.610–3, is within the range of (7:1 to 20:1). Compliance with this dilution factor range may be determined for an individual test interval or as a time-weighted average over the entire duty cycle as determined in Eq. 1066.610–4. The maximum dilution factor limit of 20:1 does not apply for hybrid electric vehicles (HEVs), since the dilution factor is infinite when the engine is off; however we strongly recommend that you stay under the specified maximum dilution factor limit when the engine is running. For partial-flow sampling systems, determine dilution factor using Eq. 1066.610–3. To determine the overall dilution factor for PM samples utilizing secondary dilution air, multiply the dilution factor from the CVS by the dilution ratio of secondary dilution air to primary diluted exhaust.

(C) You may use a higher target filter face velocity as specified in 40 CFR 1065.170(c)(1)(vi), up to 140 cm/s, if you need to increase filter loading for PM measurement.

(iv) In addition to the allowances in 40 CFR 1065.140(c)(6), you may heat the dilution air as described in paragraph (b)(2)(iii)(A) of this section to prevent or limit aqueous condensation.

(v) If you choose to dilute the exhaust by using a remote mix tee, which dilutes the exhaust at the tailpipe, you may use the following provisions consistent with good engineering judgment, as long as they do not affect your ability to demonstrate compliance with the applicable standards in this chapter:

(A) You may use smooth-walled flexible tubing (including accordion-style) in the dilution tunnel upstream of locations for flow measurement or gaseous emission measurement.

(B) You may use smooth-walled electrically conductive flexible tubing in the dilution tunnel upstream of the location for PM emission measurements.

(C) All inside surfaces upstream of emission sampling must be made of 300 series stainless steel or polymer-based materials.

(D) Use good engineering judgment to ensure that the materials you choose do not cause significant loss of PM from your sample.

(vi) Paragraph (b)(1)(vi) of this section applies instead of 40 CFR 1065.145(b).

(vii) Vehicles other than HEVs that apply technology involving engine shutdown during idle may apply the sampling provisions of § 1066.501(c).

(c) The following table summarizes the requirements of paragraph (b)(2) of this section:

TABLE 1 OF § 1066.110—SUMMARY OF EQUIPMENT SPECIFICATIONS FROM 40 CFR PART 1065, SUBPART B, THAT APPLY FOR CHASSIS TESTING

40 CFR part 1065 references	Applicability for chassis testing under this part
40 CFR 1065.140	Use all except as noted: 40 CFR 1065.140(b) applies as described in this section. Use 40 CFR 1065.140(c)(6), with the additional allowance described in this section. Do not use 40 CFR 1065.140(d)(2)(iv). Use 40 CFR 1065.140(e)(1) as described in this section. Do not use 40 CFR 1065.140(e)(2).
40 CFR 1065.145	Use all except 40 CFR 1065.145(b).
40 CFR 1065.150	Use all.
40 CFR 1065.170	Use all except as noted: Use 40 CFR 1065.170(c)(1)(vi) as described in this section.
40 CFR 1065.190	Use all.

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74196, Oct. 25, 2016; 88 FR 4708, Jan. 24, 2023]

§ 1066.120 Measurement instruments.

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

(a) The provisions of § 1066.125 apply instead of 40 CFR 1065.202.

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

§ 1066.125 Data updating, recording, and control.

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

(a) Read and record values and calculate mean values relative to a specified frequency as follows:

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

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

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

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

TABLE 1 OF § 1066.125—DATA RECORDING AND CONTROL MINIMUM FREQUENCIES

Applicable section	Measured values	Minimum command and control frequency [a]	Minimum recording frequency [b c]
§ 1066.310 § 1066.315	Vehicle speed		10 Hz.
§ 1066.425	Continuous concentrations of raw or dilute analyzers.		1 Hz.
§ 1066.425 § 1066.501	Power analyzer		1 Hz.
§ 1066.425	Bag concentrations of raw or dilute analyzers		1 mean value per test interval.
40 CFR 1065.545 § 1066.425	Diluted exhaust flow rate from a CVS with a heat exchanger upstream of the flow measurement.		1 Hz.
40 CFR 1065.545 § 1066.425	Diluted exhaust flow rate from a CVS without a heat exchanger upstream of the flow measurement.	5 Hz	1 Hz means.
40 CFR 1065.545 § 1066.425	Dilution air flow if actively controlled (for example, a partial-flow PM sampling system) [d].	5 Hz	1 Hz means.
40 CFR 1065.545 § 1066.425	Sample flow from a CVS that has a heat exchanger	1 Hz	1 Hz.
40 CFR 1065.545 § 1066.425	Sample flow from a CVS that does not have a heat exchanger.	5 Hz	1 Hz means.
§ 1066.420	Ambient temperature		1 Hz.[e]
§ 1066.420	Ambient humidity		1 Hz.[e]
§ 1066.420	Heated sample system temperatures, including PM filter face.		1 Hz.

[a] CFVs that are not using active control are exempt from meeting this requirement due to their operating principle.

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

[c] For CFVs in a CVS, the minimum recording frequency is 1 Hz. For CFVs used to control sampling from a CFV CVS, the minimum recording frequency is not applicable.

[d] This is not applicable to CVS dilution air.

[e] Unless specified elsewhere in this part or the standard-setting part. Note that this provision does not apply to soak periods where recording frequencies are not specified. For these instances, we recommend a recording frequency of ≥0.016 Hz.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9120, Feb. 19, 2015]

§ 1066.130 Measurement instrument calibrations and verifications.

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

(a) The calibration and verification provisions of 40 CFR 1065.303 do not apply for engine speed, torque, fuel rate, or intake air flow.

(b) The linearity verification provisions of 40 CFR 1065.307 do not apply for engine speed, torque, fuel rate, or intake air flow. Section 1066.135 specifies additional linearity verification provisions that apply specifically for chassis testing.

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

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

(e) If you are measuring flow volumetrically (rather than measuring based on molar values), the provisions of § 1066.140 apply instead of 40 CFR 1065.340.

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

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

TABLE 1 OF § 1066.130—SUMMARY OF REQUIRED CALIBRATIONS AND VERIFICATIONS

Type of calibration or verification	Minimum frequency [a]
40 CFR 1065.307: Linearity verification.	The linearity verifications from 40 CFR part 1065 do not apply under this part for engine speed, torque, fuel rate, or intake air flow; the linearity verification described in § 1066.135 applies for the following measurements: Dynamometer speed: See § 1066.220. Dynamometer torque: See § 1066.220.
40 CFR 1065.310: Torque	This calibration does not apply for testing under this part; see § 1066.220.
40 CFR 1065.320: Fuel flow	This calibration does not apply for testing under this part.
40 CFR 1065.325: Intake flow	This calibration does not apply for testing under this part.
40 CFR 1065.340: CVS calibration.	This calibration does not apply for CVS flow meters calibrated volumetrically as described in § 1066.140.
40 CFR 1065.345: Vacuum leak.	Required upon initial installation of the sampling system; recommended within 35 days before the start of an emissions test and after maintenance such as pre-filter changes.
40 CFR 1065.350(c), 1065.355(c), 1065.370(c), and 1065.375(c).	These provisions do not apply for testing under this part; see § 1066.150.
40 CFR 1065.395: Inertial PM balance and weighing.	These verifications do not apply for testing under this part.

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

§ 1066.135 Linearity verification.

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

(a) For gas analyzer linearity, use one of the following options:

(1) Use instrument manufacturer recommendations and good engineering judgment to select at least ten reference values, y_{refi}, that cover the range of values that you expect during testing (to prevent extrapolation beyond the verified range during emission testing). We recommend selecting zero as one of your reference values. For each range calibrated, if the deviation from a least-squares best-fit straight line is 2% or less of the value at each data point, concentration values may be calculated by use of a straight-line curve fit for that range. If the deviation exceeds 2% at any point, use the best-fit nonlinear equation that represents the data to within 2% of each test point to determine concentration. If you use a gas divider to blend calibration gases, you may verify that the calibration curve produced names a calibration gas within 2% of its certified concentration. Perform this verification between

10 and 60% of the full-scale analyzer range.

(2) Use the linearity requirements of 40 CFR 1065.307, except for CO_2 measurements used for determining fuel economy and GHG emissions for motor vehicles at or below 14,000 pounds GVWR. If you choose this linearity option, you must use the provisions of 40 CFR 1065.672 to check for drift and make appropriate drift corrections.

(b) For dilution air, diluted exhaust, and raw exhaust sample flow, use a reference flow meter with a blower or pump to simulate flow rates. Use a restrictor, diverter valve, variable-speed blower, or variable-speed pump to control the range of flow rates. Use the reference meter's response for the reference values.

(1) *Reference flow meters.* Because of the large range in flow requirements, we allow a variety of reference meters. For example, for diluted exhaust flow for a full-flow dilution system, we recommend a reference subsonic venturi flow meter with a restrictor valve and a blower to simulate flow rates. For dilution air, diluted exhaust for partial-flow dilution, and raw exhaust, we allow reference meters such as critical flow orifices, critical flow venturis, laminar flow elements, master mass flow standards, or Roots meters. Make sure the reference meter is calibrated and its calibration is NIST-traceable. If you use the difference of two flow measurements to determine a net flow rate, you may use one of the measurements as a reference for the other.

(2) *Reference flow values.* Because the reference flow is not absolutely constant, sample and record values of $\dot{Q}_{refi}$ for 30 seconds and use the arithmetic mean of the values, $\bar{\dot{Q}}_{ref}$, as the reference value. Refer to 40 CFR 1065.602 for an example of calculating an arithmetic mean.

(3) *Linearity criteria.* The values measured during linearity verification for flow meters must meet the following criteria: $| x_{min}(a_1 - 1) + a_0 | \leq 1\% \cdot \dot{Q}_{max}$; $a_1 = 0.98 - 1.02$; $SEE = \leq 2\% \cdot \dot{Q}_{max}$; and $r^2 \geq 0.990$.

(c) Perform linearity verifications for the following temperature measurements instead of those specified at 40 CFR 1065.307(e)(7):

(1) Test cell ambient air.

(2) Dilution air for PM sampling, including CVS, double-dilution, and partial-flow systems.

(3) PM sample.

(4) Chiller sample, for gaseous sampling systems that use thermal chillers to dry samples, and that use chiller temperature to calculate dewpoint at the chiller outlet. For testing, if you choose to use the high alarm temperature setpoint for the chiller temperature as a constant value in determining the amount of water removed from the emission sample, you may verify the accuracy of the high alarm temperature setpoint using good engineering judgment without following the linearity verification for chiller temperature. We recommend that you input a simulated reference temperature signal below the alarm setpoint, increase this signal until the high alarm trips, and verify that the alarm setpoint value is no less than 2 °C below the reference value at the trip point.

(5) CVS flow meter inlet temperature.

(d) Perform linearity verifications for the following pressure measurements instead of those specified at 40 CFR 1065.307(e)(8):

(1) Raw exhaust static pressure control.

(2) Barometric pressure.

(3) CVS flow meter inlet pressure.

(4) Sample dryer, for gaseous sampling systems that use either osmotic-membrane dryers or thermal chillers to dry samples. For your testing, if you choose to use a low alarm pressure setpoint for the sample dryer pressure as a constant value in determining the amount of water removed from the emission sample, you may verify the accuracy of the low alarm pressure setpoint using good engineering judgment without following the linearity verification for sample dryer pressure. We recommend that you input a reference pressure signal above the alarm setpoint, decrease this signal until the low alarm trips, and verify that the alarm setpoint value is no more than 4 kPa above the reference value at the trip point.

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

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74197, Oct. 25, 2016; 86 FR 34581, June 29, 2021]

§ 1066.140 Diluted exhaust flow calibration.

(a) *Overview*. This section describes how to calibrate flow meters for diluted exhaust constant-volume sampling (CVS) systems. We recommend that you also use this section to calibrate flow meters that use a subsonic venturi or ultrasonic flow to measure raw exhaust flow. You may follow the molar flow calibration procedures in 40 CFR 1065.340 instead of the procedures in this section.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(8) Repeat the steps in paragraphs (f)(6) and (7) of this section to record data at a minimum of six restrictor positions ranging from the wide-open restrictor position to the minimum expected pressure at the PDP inlet or the maximum expected differential (outlet

minus inlet) pressure across the PDP during testing.

(9) Calibrate the PDP by using the collected data and the equations in §1066.625(a).

(10) Repeat the steps in paragraphs (f)(6) through (9) of this section for each speed at which you operate the PDP.

(11) Use the equations in §1066.630(a) to determine the PDP flow equation for emission testing.

(12) Verify the calibration by performing a CVS verification (i.e., propane check) as described in 40 CFR 1065.341.

(13) During emission testing ensure that the PDP is not operated either below the lowest inlet pressure point or above the highest differential pressure point in the calibration data.

(g) *SSV calibration.* Calibrate each subsonic venturi (SSV) to determine its discharge coefficient, C_d, for the expected range of inlet pressures. Calibrate an SSV flow meter as follows:

(1) Configure your calibration system as shown in Figure 1 of this section.

(2) Verify that any leaks between the calibration flow meter and the SSV are less than 0.3% of the total flow at the highest restriction.

(3) Start the blower downstream of the SSV.

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

(5) Set the variable restrictor or variable-speed blower to a flow rate greater than the greatest flow rate expected during testing. You may not extrapolate flow rates beyond calibrated values, so we recommend that you make sure the Reynolds number, $Re^{\#}$, at the SSV throat at the greatest calibrated flow rate is greater than the maximum $Re^{\#}$ expected during testing.

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

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

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

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

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

(7) Incrementally close the restrictor valve or decrease the blower speed to decrease the flow rate.

(8) Repeat the steps in paragraphs (g)(6) and (7) of this section to record data at a minimum of ten flow rates.

(9) Determine an equation to quantify C_d as a function of $Re^{\#}$ by using the collected data and the equations in §1066.625(b). Section 1066.625 also includes statistical criteria for validating the C_d versus $Re^{\#}$ equation.

(10) Verify the calibration by performing a CVS verification (i.e., propane check) as described in 40 CFR 1065.341 using the new C_d versus $Re^{\#}$ equation.

(11) Use the SSV only between the minimum and maximum calibrated $Re^{\#}$. If you want to use the SSV at a lower or higher $Re^{\#}$, you must recalibrate the SSV.

(12) Use the equations in §1066.630(b) to determine SSV flow during a test.

(h) *CFV calibration.* The calibration procedure described in this paragraph (h) establishes the value of the calibration coefficient, K_v, at measured values of pressure, temperature and air flow. Calibrate the CFV up to the highest expected pressure ratio, *r*, according to §1066.625. Calibrate the CFV as follows:

(1) Configure your calibration system as shown in Figure 1 of this section.

(2) Verify that any leaks between the calibration flow meter and the CFV are less than 0.3% of the total flow at the highest restriction.

(3) Start the blower downstream of the CFV.

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

(5) Set the variable restrictor to its wide-open position. Instead of a variable restrictor, you may alternately vary the pressure downstream of the CFV by varying blower speed or by introducing a controlled leak. Note that

some blowers have limitations on non-loaded conditions.

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

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

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

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

(iv) The mean static differential pressure between the CFV inlet and the CFV outlet, $\Delta\bar{p}_{CFV}$.

(7) Incrementally close the restrictor valve or decrease the downstream pressure to decrease the differential pressure across the CFV, Δp_{CFV}.

(8) Repeat the steps in paragraphs (h)(6) and (7) of this section to record mean data at a minimum of ten restrictor positions, such that you test the fullest practical range of $\Delta\bar{p}_{CFV}$ expected during testing. We do not require that you remove calibration components or CVS components to calibrate at the lowest possible restriction.

(9) Determine K_v and the highest allowable pressure ratio, r, according to §1066.625.

(10) Use K_v to determine CFV flow during an emission test. Do not use the CFV above the highest allowed r, as determined in §1066.625.

(11) Verify the calibration by performing a CVS verification (i.e., propane check) as described in 40 CFR 1065.341.

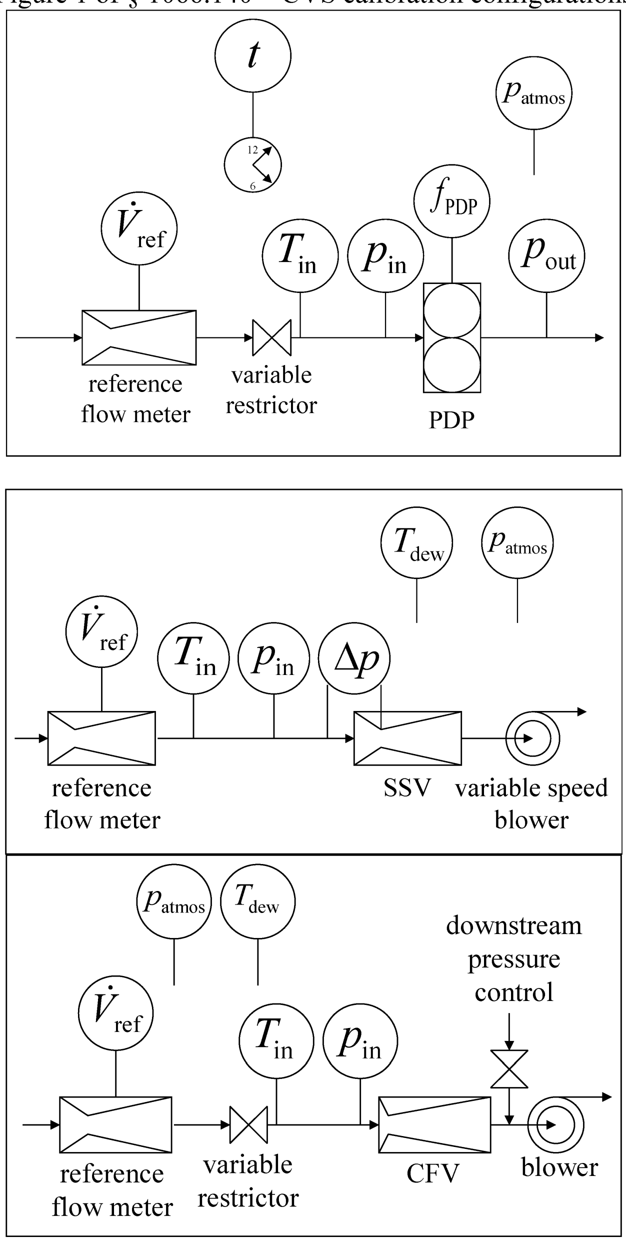
(12) If your CVS is configured to operate multiple CFVs in parallel, calibrate your CVS using one of the following methods:

(i) Calibrate every combination of CFVs according to this section and §1066.625(c). Refer to §1066.630(c) for instructions on calculating flow rates for this option.

(ii) Calibrate each CFV according to this section and §1066.625. Refer to §1066.630 for instructions on calculating flow rates for this option.

(i) *Ultrasonic flow meter calibration.* [Reserved]

Figure 1 of § 1066.140—CVS calibration configurations



[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74197, Oct. 25, 2016]

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

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

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

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

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

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

§ 1066.150 Analyzer interference and quench verification limit.

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

TABLE 1 OF § 1066.150—ANALYZER INTERFERENCE AND QUENCH VERIFICATION LIMITS

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

Subpart C—Dynamometer Specifications

§ 1066.201 Dynamometer overview.

This subpart addresses chassis dynamometers and related equipment.

§ 1066.210 Dynamometers.

(a) *General requirements*. A chassis dynamometer typically uses electrically generated load forces combined with its rotational inertia to recreate the mechanical inertia and frictional forces that a vehicle exerts on road surfaces (known as "road load"). Load forces are calculated using vehicle-specific coefficients and response characteristics. The load forces are applied to the vehicle tires by rolls connected to motor/absorbers. The dynamometer uses a load cell to measure the forces the dynamometer rolls apply to the vehicle's tires.

(b) *Accuracy and precision*. The dynamometer's output values for road load must be NIST-traceable. We may determine traceability to a specific national or international standards organization to be sufficient to demonstrate NIST-traceability. The force-measurement system must be capable of indicating force readings as follows:

(1) For dynamometer testing of vehicles at or below 20,000 pounds GVWR, the dynamometer force-measurement system must be capable of indicating force readings during a test to a resolution of ±0.05% of the maximum load-cell force simulated by the dynamometer or ±9.8 N (±2.2 lbf), whichever is greater.

(2) For dynamometer testing of vehicles above 20,000 pounds GVWR, the force-measurement system must be capable of indicating force readings during a test to a resolution of ±0.05% of the maximum load-cell force simulated by the dynamometer or ±39.2 N (±8.8 lbf), whichever is greater.

(c) *Test cycles*. The dynamometer must be capable of fully simulating vehicle performance over applicable test cycles for the vehicles being tested as referenced in the corresponding standard-setting part, including operation at the combination of inertial and road-load forces corresponding to maximum road-load conditions and maximum simulated inertia at the highest acceleration rate experienced during testing.

(d) *Component requirements*. The following specifications apply:

(1) The nominal roll diameter must be 120 cm or greater. The dynamometer must have an independent drive roll for each drive axle as tested under §1066.410(g), except that two drive axles may share a single drive roll. Use good engineering judgment to ensure that

the dynamometer roll diameter is large enough to provide sufficient tire-roll contact area to avoid tire overheating and power losses from tire-roll slippage.

(2) Measure and record force and speed at 10 Hz or faster. You may convert measured values to 1-Hz, 2-Hz, or 5-Hz values before your calculations, using good engineering judgment.

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

$$FR_{\mathrm{i}} = A \cdot \cos\left(\mathrm{atan}\left(G_{\mathrm{i-1}}\right)\right) + B \cdot v_{\mathrm{i}} + C \cdot v_{\mathrm{i}}^2 + M_{\mathrm{e}} \cdot \frac{v_{\mathrm{i}} - v_{\mathrm{i-1}}}{t_{\mathrm{i}} - t_{\mathrm{i-1}}} + M \cdot a_{\mathrm{g}} \cdot \sin\left(\mathrm{atan}\left(G_{\mathrm{i-1}}\right)\right)$$

Eq. 1066.210-1

Where:

FR = total road-load force to be applied at the surface of the roll. The total force is the sum of the individual tractive forces applied at each roll surface.

i = a counter to indicate a point in time over the driving schedule. For a dynamometer operating at 10-Hz intervals over a 600-second driving schedule, the maximum value of *i* should be 6,000.

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

G_i = instantaneous road grade, in percent. If your duty cycle is not subject to road grade, set this value to 0.

B = a vehicle-specific coefficient representing load from drag and rolling resistance, which are a function of vehicle speed, in lbf/(mi/hr) or N·s/m. See subpart D of this part.

v = instantaneous linear speed at the roll surfaces as measured by the dynamometer, in mi/hr or m/s. Let $v_{i-1} = 0$ for $i = 0$.

C = a vehicle-specific coefficient representing aerodynamic effects, which are a function of vehicle speed squared, in lbf/(mi/hr)^2 or N·s^2/m^2. See subpart D of this part.

M_e = the vehicle's effective mass in lbm or kg, including the effect of rotating axles as specified in §1066.310(b)(7).

t = elapsed time in the driving schedule as measured by the dynamometer, in seconds. Let $t_{i-1} = 0$ for $i = 0$.

M = the measured vehicle mass, in lbm or kg.

a_g = acceleration of Earth's gravity = 9.80665 m/s^2.

(4) We recommend that a dynamometer capable of testing vehicles at or below 20,000 pounds GVWR be designed to apply an actual road-load force within ±1% or ±9.8 N (±2.2 lbf) of the reference value, whichever is greater. Note that slightly higher errors may be expected during highly transient operation for vehicles above 8,500 pounds GVWR.

(e) *Dynamometer manufacturer instructions.* This part specifies that you follow the dynamometer manufacturer's recommended procedures for things such as calibrations and general operation. If you perform testing with a dynamometer that you manufactured or if you otherwise do not have these recommended procedures, use good engineering judgment to establish the additional procedures and specifications we specify in this part, unless we specify otherwise. Keep records to describe these recommended procedures and how they are consistent with good engineering judgment, including any quantified error estimates.

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74198, Oct. 25, 2016; 86 FR 34581, June 29, 2021]

§ 1066.215 Summary of verification procedures for chassis dynamometers.

(a) *Overview.* This section describes the overall process for verifying and calibrating the performance of chassis dynamometers.

(b) *Scope and frequency.* The following table summarizes the required and recommended calibrations and verifications described in this subpart and indicates when they must occur:

TABLE 1 OF § 1066.215—SUMMARY OF REQUIRED DYNAMOMETER VERIFICATIONS

Type of verification	Minimum frequency [a]
§ 1066.220: Linearity verification	Speed: Upon initial installation, within 370 days before testing, and after major maintenance. Torque (load): Upon initial installation and after major maintenance.
§ 1066.225: Roll runout and diameter verification.	Upon initial installation and after major maintenance.
§ 1066.230: Time verification	Upon initial installation and after major maintenance.
§ 1066.235: Speed measurement verification.	Upon initial installation, within 370 days before testing, and after major maintenance.
§ 1066.240: Torque (load) transducer verification.	Upon initial installation, within 7 days of testing, and after major maintenance.
§ 1066.245: Response time verification	Upon initial installation, within 370 days before testing, and after major maintenance.
§ 1066.250: Base inertia verification	Upon initial installation and after major maintenance.
§ 1066.255: Parasitic loss verification	Upon initial installation, after major maintenance, and upon failure of a verification in § 1066.270 or § 1066.275.
§ 1066.260: Parasitic friction compensation verification.	Upon initial installation, after major maintenance, and upon failure of a verification in § 1066.270 or § 1066.275.
§ 1066.265: Acceleration and deceleration verification.	Upon initial installation and after major maintenance.
§ 1066.270: Unloaded coastdown verification.	Upon initial installation, within 7 days of testing, and after major maintenance.
§ 1066.275 Dynamometer readiness verification.	Upon initial installation, within 1 day before testing, and after major maintenance.

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

(c) *Automated dynamometer verifications and calibrations.* In some cases, dynamometers are designed with internal diagnostic and control features to accomplish the verifications and calibrations specified in this subpart. You may use these automated functions instead of following the procedures we specify in this subpart to demonstrate compliance with applicable requirements, consistent with good engineering judgment.

(d) *Sequence of verifications and calibrations.* Upon initial installation and after major maintenance, perform the verifications and calibrations in the same sequence as noted in Table 1 of this section, except that you may perform speed linearity verification after the verifications in §§ 1066.225 and 1066.230. At other times, you may need to perform specific verifications or calibrations in a certain sequence, as noted in this subpart. If you perform major maintenance on a specific component, you are required to perform verifications and calibrations only on components or parameters that are affected by the maintenance.

(e) *Corrections.* Unless the regulation directs otherwise, if the dynamometer fails to meet any specified calibration or verification, make any necessary adjustments or repairs such that the dynamometer meets the specification before running a test. Repairs required to meet specifications are generally considered major maintenance under this part.

§ 1066.220 Linearity verification for chassis dynamometer systems.

(a) *Scope and frequency.* Perform linearity verification for dynamometer speed and torque at least as frequently as indicated in Table 1 of § 1066.215. The intent of linearity verification is to determine that the system responds accurately and proportionally over the measurement range of interest. Linearity verification generally consists of introducing a series of at least 10 reference values to a measurement system. The measurement system quantifies each reference value. The measured values are then collectively compared to the reference values by using a least-squares linear regression and the linearity criteria specified in Table 1 of this section.

(b) *Performance requirements.* If a measurement system does not meet the applicable linearity criteria in Table 1 of this section, correct the deficiency by re-calibrating, servicing, or replacing components as needed. Repeat the linearity verification after correcting the deficiency to ensure that the measurement system meets the linearity criteria. Before you may use a measurement system that does not meet linearity criteria, you must demonstrate to us that the deficiency does not adversely affect your ability to demonstrate compliance with the applicable standards in this chapter.

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

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

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

(3) Set dynamometer speed and torque to zero.

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

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

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

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

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

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

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

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

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

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

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

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

[79 FR 23823, Apr. 28, 2014, as amended at 88 FR 4708, Jan. 24, 2023]

§ 1066.225 Roll runout and diameter verification procedure.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

value for all calculations in this subpart.

§ 1066.230 Time verification procedure.

(a) *Overview.* This section describes how to verify the accuracy of the dynamometer's timing device.

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

(c) *Procedure.* Perform this verification using one of the following procedures:

(1) *WWV method.* You may use the time and frequency signal broadcast by NIST from radio station WWV as the time standard if the trigger for the dynamometer timing circuit has a frequency decoder circuit, as follows:

(i) Contact station WWV by telephone by dialing (303) 499–7111 and listen for the time announcement. Verify that the trigger started the dynamometer timer. Use good engineering judgment to minimize error in receiving the time and frequency signal.

(ii) After at least 1000 seconds, re-dial station WWV and listen for the time announcement. Verify that the trigger stopped the dynamometer timer.

(iii) Compare the measured elapsed time, y_{act}, to the corresponding time standard, y_{ref}, to determine the time error, y_{error}, using the following equation:

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

Eq. 1066.230-1

(2) *Ramping method.* You may use an operator-defined ramp function to serve as the time standard as follows:

(i) Set up a signal generator to output a marker voltage at the peak of each ramp to trigger the dynamometer timing circuit. Output the designated marker voltage to start the verification period.

(ii) After at least 1000 seconds, output the designated marker voltage to end the verification period.

(iii) Compare the measured elapsed time between marker signals, y_{act}, to the corresponding time standard, y_{ref}, to determine the time error, y_{error}, using Eq. 1066.230–1.

(3) *Dynamometer coastdown method.* You may use a signal generator to output a known speed ramp signal to the dynamometer controller to serve as the time standard as follows:

(i) Generate upper and lower speed values to trigger the start and stop functions of the coastdown timer circuit. Use the signal generator to start the verification period.

(ii) After at least 1000 seconds, use the signal generator to end the verification period.

(iii) Compare the measured elapsed time between trigger signals, y_{act}, to the corresponding time standard, y_{ref}, to determine the time error, y_{error}, using Eq. 1066.230–1.

(d) *Performance evaluation.* The time error determined in paragraph (c) of this section may not exceed ±0.001%.

§ 1066.235 Speed verification procedure.

(a) *Overview.* This section describes how to verify the accuracy of the dynamometer speed determination. When performing this verification, you must also ensure the dynamometer speed at any devices used to display or record vehicle speed (such as a driver's aid) is representative of the speed input from the dynamometer speed determination.

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

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

(1) *Pulse method.* Connect a universal frequency counter to the output of the

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

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

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

Eq. 1066.235-1

Where:

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

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

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

Example:

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

d_{roll} = 904.40 mm = 0.90440 m

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

v_{act} = 8.3053 m/s

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

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

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

Eq. 1066.235-2

Example:

v_{act} = 8.3053 m/s

v_{ref} = 8.3000 m/s

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

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

(c)(2). Determine the speed error as follows:

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

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

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

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

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9120, Feb. 19, 2015; 81 FR 74199, Oct. 25, 2016]

§ 1066.240 Torque transducer verification.

Verify torque-measurement systems by performing the verifications described in §§ 1066.270 and 1066.275.

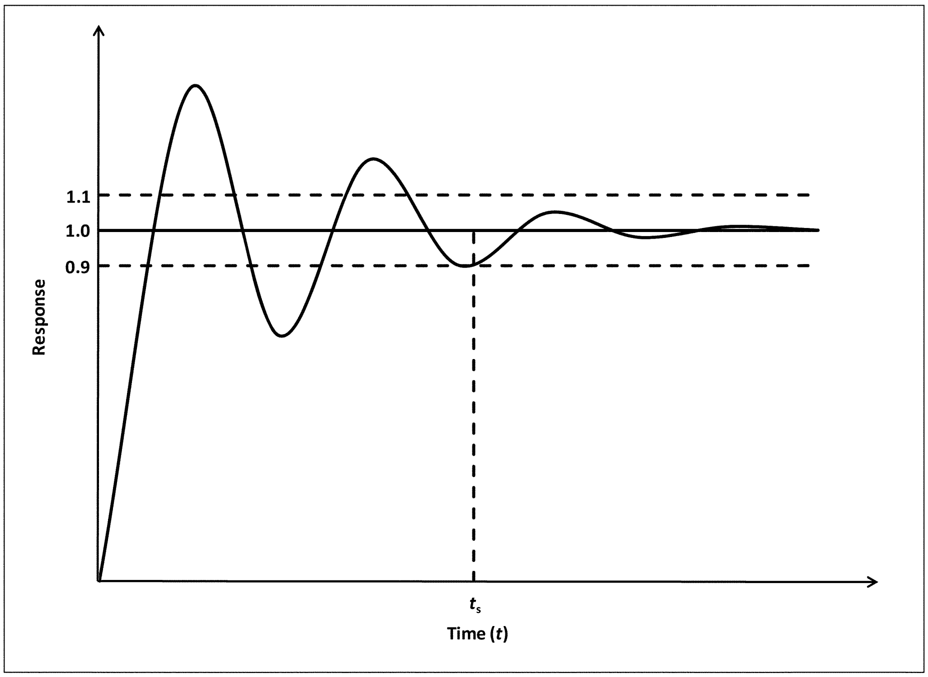
§ 1066.245 Response time verification.

(a) *Overview.* This section describes how to verify the dynamometer's response time to a step change in tractive force.

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

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

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



[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74199, Oct. 25, 2016]

§ 1066.250 Base inertia verification.

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

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

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

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

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

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

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

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

$$I_{\mathrm{b}} = \frac{\bar{F}}{\left|\frac{v_{\mathrm{final}} - v_{\mathrm{init}}}{\Delta t}\right|}$$

Eq. 1066.250-1

Where:

$\bar{F}$ = mean dynamometer force over the measurement interval as measured by the dynamometer.

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

v_{init} = roll surface speed at the start of the measurement interval to the nearest 0.01 mi/hr.

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

Example:

$\bar{F}$ = 1.500 lbf = 48.26 ft·lbm/s²

v_{final} = 40.00 mi/hr = 58.67 ft/s

v_{init} = 10.00 mi/hr = 14.67 ft/s

Δt = 30.00 s

$$I_{\mathrm{b}} = \frac{48.26}{\left|\frac{58.67 - 14.67}{30.00}\right|}$$

I_b = 32.90 lbm

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

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

Eq. 1066.250-2

Example:

I_{bref} = 32.96 lbm

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

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

$$I_{\mathrm{berror}} = 0.18\ \%$$

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

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

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

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

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

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74199, Oct. 25, 2016]

§ 1066.255 Parasitic loss verification.

(a) *Overview*. Verify the dynamometer's parasitic loss as described in this section, and correct as necessary. This procedure determines the dynamometer's internal losses that it must overcome to simulate road load. Characterize these losses in a parasitic loss curve that the dynamometer uses to apply compensating forces to maintain the desired road-load force at the roll surface.

(b) *Scope and frequency*. Perform this verification upon initial installation, after major maintenance, and upon failure of a verification in either §1066.270 or §1066.275.

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

(d) *Performance evaluation*. Some dynamometers automatically update the parasitic loss curve for further testing. If this is not the case, compare the new parasitic loss curve to the original parasitic loss curve from the dynamometer manufacturer or the most recent parasitic loss curve you programmed into the dynamometer. You may reprogram the dynamometer to accept the new curve in all cases, and you must reprogram the dynamometer if any point on the new curve departs from the earlier curve by more than ±9.0 N (±2.0 lbf) for dynamometers capable of testing vehicles at or below 20,000 pounds GVWR, or ±36.0 N (±8.0 lbf) for dynamometers not capable of testing vehicles at or below 20,000 pounds GVWR.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9120, Feb. 19, 2015; 86 FR 34581, June 29, 2021]

§ 1066.260 Parasitic friction compensation evaluation.

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

(b) *Scope and frequency*. Perform this verification upon initial installation, after major maintenance, and upon failure of a verification in either §1066.270 or §1066.275. Note that this procedure relies on proper verification of speed and torque, as described in §§1066.235 and 1066.240. You must also first verify the dynamometer's parasitic loss curve as specified in § 1066.255.

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

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

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

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

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

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

Eq. 1066.260-1

Where:

I = dynamometer inertia setting.

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

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

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

Example:

I = 2000 lbm = 62.16 lbf·s²/ft

t = 60.0 s

v_{init} = 9.2 mi/hr = 13.5 ft/s

v_{final} = 10.0 mi/hr = 14.7 ft/s

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

FC_{error} = –17.5 ft·lbf/s = – 0.032 hp

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

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74200, Oct. 25, 2016; 86 FR 34581, June 29, 2021]

§ 1066.265 Acceleration and deceleration verification.

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

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

(c) *Verification of acceleration and deceleration rates*. Activate the dynamometer's function generator for measuring roll revolution frequency. If the dynamometer has no such function generator, set up a properly calibrated external function generator consistent with the verification described in this paragraph (c). Use the function generator to determine actual acceleration and deceleration rates as the dynamometer traverses speeds between 10 and 40 mi/hr at various nominal acceleration and deceleration rates. Verify the dynamometer's acceleration and deceleration rates as follows:

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

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

Eq. 1066.265-1

Where:

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

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

d_{roll} = roll diameter, in inches.

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

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

Eq. 1066.265-2

Where:

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

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

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

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

Example:

v_{final} = 40 mi/hr

v_{init} = 10 mi/hr

t = 30.003 s

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

a_{act} = 0.999 (mi/hr)/s

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

(4) Repeat the steps in paragraphs (c)(2) and (3) of this section for additional acceleration and deceleration rates in 1 (mi/hr)/s increments up to and including one increment above the maximum acceleration rate expected during testing. Average the five repeat runs to calculate a mean acceleration rate, $\bar{a}_{act}$, at each setting.

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

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

Eq. 1066.265-3

Example:

$\bar{a}_{act}$ = 0.999 (mi/hr)/s

a_{ref} = 1 (mi/hr)/s

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

a_{error} = −0.100%

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

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

$$F = I_b \cdot |a|$$

Eq. 1066.265-4

Where:

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

a = nominal acceleration rate, in ft/s².

Example:

I_b = 2967 lbm = 92.217 lbf·s²/ft

a = 1 (mi/hr)/s = 1.4667 ft/s²

F = 92.217·|1.4667|

F = 135.25 lbf

(2) Set the dynamometer to road-load mode and program it with a calculated force to accelerate the roll at a nominal rate of 1 (mi/hr)/s from 10 mi/hr to 40 mi/hr. Measure the elapsed time to reach the target speed, to the nearest 0.01 s. Repeat this measurement for a total of five runs. Determine the actual

acceleration rate, a_{act}, for each run using Eq. 1066.265–2. Repeat this step to determine measured ''negative acceleration'' rates using a calculated force to decelerate the roll at a nominal rate of 1 (mi/hr)/s from 40 mi/hr to 10 mi/hr. Average the five repeat runs to calculate a mean acceleration rate, $\bar{a}_{act}$, at each setting.

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

(4) Compare each mean acceleration rate, $\bar{a}_{act}$, to the corresponding nominal acceleration rate, $\bar{a}_{ref}$, to determine values for acceleration error, $\bar{a}_{error}$, using Eq. 1066.265–3.

(e) *Performance evaluation.* The acceleration error from paragraphs (c)(5) and (d)(4) of this section may not exceed ±1.0%.

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74200, Oct. 25, 2016; 86 FR 34582, June 29, 2021]

§ 1066.270 Unloaded coastdown verification.

(a) *Overview.* Use force measurements to verify the dynamometer's settings based on coastdown procedures.

(b) *Scope and frequency.* Perform this verification upon initial installation, within 7 days of testing, and after major maintenance.

(c) *Procedure.* This procedure verifies the dynamometer's settings derived from coastdown testing. For dynamometers that have an automated process for this procedure, perform this evaluation by setting the initial speed, final speed, inertial coefficients, and road-load coefficients as required for each test, using good engineering judgment to ensure that these values properly represent in-use operation. Use the following procedure if your dynamometer does not perform this verification with an automated process:

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

(2) With the dynamometer in coastdown mode, set the dynamometer inertia for the smallest vehicle weight that you expect to test and set A, B, and C road-load coefficients to values typical of those used during testing. Program the dynamometer to coast down over the dynamometer operational speed range (typically from a speed of 80 mi/hr through a minimum speed at or below 10 mi/hr). Perform at least one coastdown run over this speed range, collecting data over each 10 mi/hr interval.

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

(4) Determine the mean coastdown force, $\bar{F}$, for each speed and inertia setting for each of the coastdowns performed using the following equation:

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

Eq. 1066.270-1

Where:

$\bar{F}$ = the mean force measured during the coastdown for each speed interval and inertia setting, expressed in lbf and rounded to four significant figures.

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

v_{init} = the speed at the start of the coastdown interval, expressed in ft/s to at least four significant figures.

v_{final} = the speed at the end of the coastdown interval, expressed in ft/s to at least four significant figures.

t = coastdown time for each speed interval and inertia setting, accurate to at least 0.01 s.

Example:

I = 2000 lbm = 62.16 lbf·s²/ft

v_{init} = 25 mi/hr = 36.66 ft/s

v_{final} = 15 mi/hr = 22.0 ft/s

t = 5.00 s

$$\bar{F} = \frac{62.16 \cdot (36.66 - 22.0)}{5.00}$$

$\bar{F}$ = 182.3 lbf

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

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

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

Eq. 1066.270-2

Example:

F_{ref} = 192 lbf

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

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

F_{error} = 0.5%

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

(1) For vehicles at or below 20,000 pounds GVWR, the maximum allowable error, $F_{errormax}$, for all speed intervals and inertia settings is 1.0% or the value determined from Eq. 1066.270–3, whichever is greater.

$$F_{errormax} = \frac{2.2 \text{ lbf}}{F_{ref}} \cdot 100$$

Eq. 1066.270-3

Example:

F_{ref} = 192 lbf

$$F_{errormax} = \frac{2.2 \text{ lbf}}{192} \cdot 100$$

$F_{errormax} = 1.14\%$

(2) For vehicles above 20,000 pounds GVWR, the maximum allowable error, $F_{errormax}$, for all speed intervals and inertia settings is 1.0% or the value determined from Eq. 1066.270–3 (substituting 8.8 lbf for 2.2 lbf in the numerator), whichever is greater.

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

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9120, Feb. 19, 2015; 81 FR 74201, Oct. 25, 2016; 86 FR 34582, June 29, 2021]

§ 1066.275 Daily dynamometer readiness verification.

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

(b) *Scope and frequency.* Perform this verification upon initial installation, within 1 day before testing, and after major maintenance. You may run this within 7 days before testing if you accumulate data to support a less frequent verification interval.

(c) *Procedure.* For dynamometers that have an automated process for this verification procedure, perform this evaluation by setting the initial speed and final speed and the inertial and road-load coefficients as required for the test, using good engineering judgment to ensure that these values properly represent in-use operation. Use the following procedure if your dynamometer does not perform this verification with an automated process:

(1) With the dynamometer in coastdown mode, set the dynamometer inertia to the base inertia with the road-load coefficient A set to 20 lbf (or a force that results in a coastdown time of less than 10 minutes) and coefficients B and C set to 0. Program the dynamometer to coast down for one 10 mi/hr interval from 55 mi/hr down to 45 mi/hr. If your dynamometer is not capable of performing one discrete coastdown, then coast down with preset 10 mi/hr intervals that include a 55 mi/hr to 45 mi/hr interval.

(2) Perform the coastdown.

(3) Determine the coastdown force and coastdown force error using Eqs. 1066.270–1 and 1066.270–2.

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

(1) For vehicles at or below 20,000 pounds GVWR, 1.0% or the value determined from Eq. 1066.270–3, whichever is greater.

(2) For vehicles above 20,000 pounds GVWR, 1.0% or the value determined from Eq. 1066.270–3 (substituting 8.8 lbf for 2.2 lbf), whichever is greater.

(e) *Remedy for nonconforming dynamometers.* If the verification results fail to meet the performance criteria in paragraph (d) of this section, perform the procedure up to two additional times. If the dynamometer is consistently unable to meet the performance criteria, diagnose and repair the dynamometer before continuing with emission testing. Diagnosis should include performing the verifications in § 1066.255 and § 1066.260.

[79 FR 23823, Apr. 28, 2014, as amended at 81 FR 74201, Oct. 25, 2016; 86 FR 34582, June 29, 2021]

§ 1066.290 Verification of speed accuracy for the driver's aid.

Use good engineering judgment to provide a driver's aid that facilitates compliance with the requirements of § 1066.425. Verify the speed accuracy of the driver's aid as described in § 1066.235.

Subpart D—Coastdown

§ 1066.301 Overview of road-load determination procedures.

Vehicle testing on a chassis dynamometer involves simulating the road-load force, which is the sum of forces acting on a vehicle from aerodynamic drag, tire rolling resistance, driveline losses, and other effects of friction. Determine dynamometer settings to simulate road-load force in two stages. First, perform a road-load force specification by characterizing on-road operation. Second, perform a road-load derivation to determine the appropriate dynamometer load settings to simulate the road-load force specification from the on-road test.

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

(b) The general procedure for determining road-load force is performing coastdown tests and calculating road-load coefficients. This procedure is described in SAE J1263 and SAE J2263 (incorporated by reference, see §1066.1010). Continued testing based on the 2008 version of SAE J2263 is optional, except that it is no longer available for testing starting with model year 2026. This subpart specifies certain deviations from those procedures for certain applications.

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

[80 FR 9121, Feb. 19, 2015, as amended at 81 FR 74201, Oct. 25, 2016; 88 FR 4708, Jan. 24, 2023; 89 FR 28211, Apr. 18, 2024]

§ 1066.305 Procedures for specifying road-load forces for motor vehicles at or below 14,000 pounds GVWR.

(a) For motor vehicles at or below 14,000 pounds GVWR, develop representative road-load coefficients to characterize each vehicle covered by a certificate of conformity. Calculate road-load coefficients by performing coastdown tests using the provisions of SAE J1263 and SAE J2263 (incorporated by reference, see §1066.1010). This protocol establishes a procedure for determination of vehicle road load force for speeds between 115 and 15 km/hr (71.5 and 9.3 mi/hr); the final result is a model of road-load force (as a function of speed) during operation on a dry, level road under reference conditions of 20 °C, 98.21 kPa, no wind, no precipitation, and the transmission in neutral. You may use other methods that are equivalent to SAE J2263, such as equivalent test procedures or analytical modeling, to characterize road load using good engineering judgment. Determine dynamometer settings to simulate the road-load profile represented by these road-load target coefficients as described in §1066.315. Supply representative road-load forces for each vehicle at speeds above 15 km/hr (9.3 mi/hr), and up to 115 km/hr (71.5 mi/hr), or the highest speed from the range of applicable duty cycles.

(b) For cold temperature testing described in subpart H of this part, determine road-load target coefficients using one of the following methods:

(1) You may perform coastdown tests or use other methods to characterize road load as described in paragraph (a) of this section based on vehicle operation at a nominal ambient temperature of −7 °C (20 °F).

(2) You may multiply each of the road-load target coefficients determined using the procedures described in paragraph (a) of this section by 1.1 to approximate a 10 percent decrease in coastdown time for the test vehicle.

[80 FR 9121, Feb. 19, 2015, as amended at 81 FR 74202, Oct. 25, 2016; 89 FR 28211, Apr. 18, 2024]

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

This section describes coastdown procedures that are unique to vehicles above 14,000 pounds GVWR. These procedures are valid for calculating road-load coefficients for chassis and post-transmission powerpack testing. These procedures are also valid for calculating drag area (C_dA) to demonstrate compliance with Phase 1 greenhouse gas emission standards under 40 CFR part 1037.

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

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

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

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

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

(2) Operate the vehicle at a top speed above 70 mi/hr, or at its maximum achievable speed if it cannot reach 70 mi/hr. If a vehicle is equipped with a vehicle speed limiter that is set for a maximum speed below 70 mi/hr, you must disable the vehicle speed limiter. Start the test at or above 70 mi/hr, or at the vehicle's maximum achievable speed if it cannot reach 70 mi/hr. Collect data through a minimum speed at or below 15 mi/hr. Data analysis for valid coastdown runs must include the range of vehicle speeds specified in this paragraph (b)(2).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Eq. 1066.310-1

Where:

i = an interval counter, starting with i = 1 for the first interval. The designation (i-1) corresponds to the end of the previous interval or, for the first interval, to the start of the test run.

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

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

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

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

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

Eq. 1066.310-2

Where:

M = the measured vehicle mass, expressed to at least the nearest 0.1 kg.

a_g = acceleration of Earth's gravity, as described in 40 CFR 1065.630.

Δh = change in elevation over the measurement interval, in m. Assume Δh = 0 if you are not correcting for grade.

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

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

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

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

Eq. 1066.310-3

Where:

ρ = air density at reference conditions = 1.17 kg/m³.

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

Eq. 1066.310-4

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

$\bar{P}$ = mean ambient pressuring during the test, in kPa.

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

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

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

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

[79 FR 23823, Apr. 28, 2016, as amended at 81 FR 74202, Oct. 25, 2016; 89 FR 28211, Apr. 18, 2024]

§ 1066.315 Dynamometer road-load setting.

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

[89 FR 28212, Apr. 18, 2024]

Subpart E—Preparing Vehicles and Running an Exhaust Emission Test

§ 1066.401 Overview.

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

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

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

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

(4) Record pre-test data.

(5) Sample emissions.

(6) Record post-test data.

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

(8) Weigh PM samples.

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

(1) *Transient cycles.* Transient test cycles are typically specified in the standard-setting part as a second-by-second sequence of vehicle speed commands. Operate a vehicle over a transient cycle such that the speed follows

the target values. Proportionally sample emissions and other parameters and calculate emission rates as specified in subpart G of this part to calculate emissions. The standard-setting part may specify three types of transient testing based on the approach to starting the measurement, as follows:

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

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

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

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

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

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

§ 1066.405 Vehicle preparation, preconditioning, and maintenance.

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

(b) If you inspect a vehicle, keep a record of the inspection and update your application for certification to document any changes that result. You may use any kind of equipment, instrument, or tool that is available at dealerships and other service outlets to identify malfunctioning components or perform maintenance.

(c) You may repair defective parts from a test vehicle if they are unrelated to emission control. You must ask us to approve repairs that might affect the vehicle's emission controls. If we determine that a part failure, system malfunction, or associated repair makes the vehicle's emission controls unrepresentative of production engines, you may not use it as an emission-data vehicle. Also, if the engine installed in the test vehicle has a major mechanical failure that requires you to take the vehicle apart, you may no longer use the vehicle as an emission-data vehicle for exhaust measurements.

[86 FR 34582, June 29, 2021]

§ 1066.410 Dynamometer test procedure.

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

(b) Place the vehicle onto the dynamometer without starting the engine (for any test cycles) or drive the vehicle onto the dynamometer (for hot-start and hot-running cycles only) and position a fan that directs cooling air to the vehicle during dynamometer operation as described in this paragraph (b). This generally requires squarely positioning the fan in front of the vehicle and directing the airflow to the vehicle's radiator. Use good engineering judgment to design and configure fans to cool the test vehicle in a way that properly simulates in-use operation, consistent with the specifications of §1066.105. Except for the following special cases, use a road-speed modulated fan meeting the requirements of §1066.105(c)(2) that is placed within 90 cm of the front of the vehicle and ensure that the engine compartment cover (*i.e.*, hood) is closed:

(1) For vehicles above 14,000 pounds GVWR, use a fan meeting the requirements of §1066.105(d) that is placed within 90 cm of the front of the vehicle and ensure that the engine compartment cover is closed.

(2) For FTP, LA–92, US06, or HFET testing of vehicles at or below 14,000 pounds GVWR, you may use a fixed-speed fan as specified in the following

table, with the engine compartment cover open:

TABLE 1 OF § 1066.410—FIXED-SPEED FAN CAPACITY AND POSITION SPECIFICATIONS FOR VEHICLES AT OR BELOW 14,000 POUNDS GVWR

Test cycle	Maximum fan capacity	Approximate distance from the front of the vehicle
FTP	Up to 2.50 m^3/s	0 to 30 cm.
US06	Up to 7.10 m^3/s	0 to 60 cm.
LA–92	Up to 7.10 m^3/s	0 to 60 cm.
HFET	Up to 2.50 m^3/s	0 to 30 cm.

(3) For SC03 and AC17 testing, use a road-speed modulated fan meeting the requirements of § 1066.105(c)(5) that is placed within 60 to 90 cm of the front of the vehicle and ensure that the engine compartment cover is closed. Position the discharge nozzle such that its lowest point is not more than 16 cm above the floor of the test cell.

(c) Record the vehicle's speed trace based on the time and speed data from the dynamometer at the recording frequencies given in Table 1 of § 1066.125. Record speed to at least the nearest 0.01 mi/hr and time to at least the nearest 0.1 s.

(d) You may perform practice runs for operating the vehicle and the dynamometer controls to meet the driving tolerances specified in § 1066.425 or adjust the emission sampling equipment. Verify that the accelerator pedal allows for enough control to closely follow the prescribed driving schedule. We recommend that you verify your ability to meet the minimum dilution factor requirements of § 1066.110(b)(2)(iii)(B) during these practice runs.

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

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

(g) Use good engineering judgment when testing vehicles in four-wheel drive or all-wheel drive mode. (For purposes of this paragraph (g), the term four-wheel drive includes other multiple drive-axle configurations.) This may involve testing on a dynamometer with a separate dynamometer roll for each drive axle; or two drive axles may use a single roll, as described in § 1066.210(d)(1); or you may deactivate the second set of drive wheels and operate the vehicle on a single roll. For all vehicles at or below 14,000 GVWR, we will test your vehicle using the same dynamometer roll arrangement that you used. We may also test your vehicle using another dynamometer roll arrangement for information-gathering purposes. If we choose to perform additional testing that requires vehicle modifications, we will ask you to configure the vehicle appropriately.

(h) Determine equivalent test weight as follows:

(1) For vehicles at or below 14,000 pounds GVWR, determine ETW as described in § 1066.805. Set dynamometer vehicle inertia, *I*, based on dynamometer type, as follows:

(i) For two-wheel drive dynamometers, set $I = \text{ETW}$.

(ii) For four-wheel drive dynamometers, set $I = 0.985 \cdot \text{ETW}$.

(2) For vehicles above 14,000 pounds GVWR, determine the vehicle's effective mass as described in § 1066.310 and use this as the test weight.

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

(j) Following the test, determine the actual driving distance by counting the number of dynamometer roll or shaft revolutions, or by integrating speed over the course of testing from a high-resolution encoder system.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9121, Feb. 19, 2015; 81 FR 74202, Oct. 25, 2016]

§ 1066.415 Vehicle operation.

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

(a) Start the vehicle as follows:

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

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

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

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

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

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

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

(e) Operate vehicles during testing as follows:

(1) Where we do not give specific instructions, operate the vehicle according to the recommendations in the owners manual, unless those recommendations are unrepresentative of what may reasonably be expected for in-use operation.

(2) If vehicles have features that preclude dynamometer testing, you may modify these features as necessary to allow testing, consistent with good engineering judgment, as long as it does not affect your ability to demonstrate that your vehicles comply with the applicable standards in this chapter. Send us written notification describing these changes along with supporting rationale.

(3) Operate vehicles during idle as follows:

(i) For vehicles with automatic transmission, operate at idle with the transmission in ''Drive'' with the wheels braked, except that you may shift to ''Neutral'' for the first idle period and for any idle period longer than one minute. If you put the vehicle in ''Neutral'' during an idle, you must shift the vehicle into ''Drive'' with the wheels braked at least 5 seconds before the end of the idle period. Note that this does not preclude vehicle designs involving engine shutdown during idle.

(ii) For vehicles with manual transmission, operate at idle with the transmission in gear with the clutch disengaged, except that you may shift to ''Neutral'' with the clutch engaged for the first idle period and for any idle period longer than one minute. If you put the vehicle in ''Neutral'' during idle, you must shift to first gear with the clutch disengaged at least 5 seconds before the end of the idle period. Note that this does not preclude vehicle designs involving engine operation with shutdown during idle.

(4) Operate the vehicle with the appropriate accelerator pedal movement necessary to follow the scheduled speeds in the driving schedule. Avoid smoothing speed variations and unnecessary movement of the accelerator pedal.

(5) Operate the vehicle smoothly, following representative shift speeds and procedures. For manual transmissions, the operator shall release the accelerator pedal during each shift and accomplish the shift without delay. If the vehicle cannot accelerate at the specified rate, operate it at maximum available power until the vehicle speed reaches the value prescribed in the driving schedule.

(6) Decelerate as follows:

(i) For vehicles with automatic transmission, use the brakes or accelerator pedal as necessary, without manually changing gears, to maintain the desired speed.

(ii) For vehicles with manual transmission, shift gears in a way that represents reasonable shift patterns for in-use operation, considering vehicle speed, engine speed, and any other relevant variables. Disengage the clutch when the speed drops below 15 mi/hr, when engine roughness is evident, or when good engineering judgment indicates the engine is likely to stall. Manufacturers may recommend shift guidance in the owners manual that differs from the shift schedule used during testing, as long as both shift schedules are described in the application for certification; in this case, we may shift during testing as described in the owners manual.

[79 FR 23823, Apr. 28, 2016, as amended at 81 FR 74202, Oct. 25, 2016; 88 FR 4708, Jan. 24, 2023]

§ 1066.420 Test preparation.

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

(b) Minimize the effect of nonmethane hydrocarbon contamination in the hydrocarbon sampling system for vehicles with compression-ignition engines as follows:

(1) For vehicles at or below 14,000 pounds GVWR, account for contamination using one of the following methods:

(i) Introduce zero and span gas during analyzer calibration using one of the following methods, noting that the hydrocarbon analyzer flow rate and pressure during zero and span calibration (and background bag reading) must be exactly the same as that used during testing to minimize measurement errors:

(A) Close off the hydrocarbon sampling system sample probe and introduce gases downstream of the probe making sure that you do not pressurize the system.

(B) Introduce zero and span gas directly at the hydrocarbon sampling system probe at a flow rate greater than 125% of the hydrocarbon analyzer flow rate allowing some gas to exit probe inlet.

(ii) Perform the contamination verification in paragraph (b)(2) of this section, except use 0.5 µmol/mol in 40 CFR 1065.520(f)(8)(iii).

(2) For vehicles above 14,000 pounds GVWR, verify the amount of nonmethane hydrocarbon contamination as described in 40 CFR 1065.520(f).

(c) Unless the standard-setting part specifies different tolerances, verify at some point before the test that ambient conditions are within the tolerances specified in this paragraph (c). For purposes of this paragraph (c), ''before the test'' means any time from a point just prior to engine starting (excluding engine restarts) to the point at which emission sampling begins.

(1) Ambient temperature must be (20 to 30) °C. See § 1066.425(h) for circumstances under which ambient temperatures must remain within this range during the test.

(2) Dilution air conditions must meet the specifications in § 1066.110(b)(2). We recommend verifying dilution air conditions just before starting each test interval.

(d) Control test cell ambient air humidity as follows:

(1) For vehicles at or below 14,000 pounds GVWR, follow the humidity requirements in Table 1 of this section,

unless the standard-setting part specifies otherwise. When complying with humidity requirements in Table 1, where no tolerance is specified, use good engineering judgment to maintain the humidity level near the specified value within the limitations of your test facility.

(2) For vehicles above 14,000 pounds GVWR, you may test vehicles at any humidity.

(3) Table 1 follows:

TABLE 1 OF § 1066.420—TEST CELL HUMIDITY REQUIREMENTS

Test cycle	Humidity requirement (grains H_2O per pound dry air)	Tolerance (grains H_2O per pound dry air)
AC17	69	±5 average, ±10 instantaneous.
FTP[a] and LA–92	50	
HFET	50	
SC03	100	±5 average.
US06	50	

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

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

(f) You may perform the following procedure to precondition sampling systems:

(1) Operate the vehicle over the test cycle.

(2) Operate any dilution systems at their expected flow rates. Prevent aqueous condensation in the dilution systems as described in 40 CFR 1065.140(c)(6), taking into account allowances given in § 1066.110(b)(2)(iv).

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

(4) Sample PM using any sample media. You may change sample media during preconditioning. You must discard preconditioning samples without weighing them.

(5) You may purge any gaseous sampling systems during preconditioning.

(6) You may conduct calibrations or verifications on any idle equipment or analyzers during preconditioning.

(g) Take the following steps before emission sampling begins:

(1) For batch sampling, connect clean storage media, such as evacuated bags or tare-weighed filters.

(2) Start all measurement instruments according to the instrument manufacturer's instructions and using good engineering judgment.

(3) Start dilution systems, sample pumps, and the data-collection system.

(4) Pre-heat or pre-cool heat exchangers in the sampling system to within their operating temperature tolerances for a test.

(5) Allow heated or cooled components such as sample lines, filters, chillers, and pumps to stabilize at their operating temperatures.

(6) Adjust the sample flow rates to desired levels using bypass flow, if desired.

(7) Zero or re-zero any electronic integrating devices before the start of any test interval.

(8) Select gas analyzer ranges. You may not switch the gain of an analyzer's analog operational amplifier(s) during a test. However, you may switch (automatically or manually) gas analyzer ranges during a test if such switching changes only the range over which the digital resolution of the instrument is applied. For batch analyzers, select ranges before final bag analysis.

(9) Zero and span all continuous gas analyzers using gases that meet the specifications of 40 CFR 1065.750. For FID analyzers, you may account for the carbon number of your span gas either during the calibration process or when calculating your final emission value. For example, if you use a C_3H_8 span gas of concentration 200 ppm (µmol/mol), you may span the FID to respond with a value of 600 ppm (µmol/mol) of carbon or 200 ppm of propane. However, if your FID response is equivalent to propane, include a factor of three to make the final calculated hydrocarbon mass consistent with a molar mass of 13.875389. When utilizing an NMC–FID, span the FID analyzer consistent with the determination of their respective response factors, *RF*, and penetration fractions, *PF*, according to 40 CFR 1065.365.

(10) We recommend that you verify gas analyzer responses after zeroing and spanning by sampling a calibration gas that has a concentration near one-half of the span gas concentration.

Based on the results, use good engineering judgment to decide whether or not to re-zero, re-span, or re-calibrate a gas analyzer before starting a test.

(11) If you correct for dilution air background concentrations of associated engine exhaust constituents, start sampling and recording background concentrations at the same time you start sampling exhaust gases.

(12) Turn on cooling fans immediately before starting the test.

(h) Proceed with the test sequence described in §1066.425.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9121, Feb. 19, 2015; 86 FR 34582, June 29, 2021; 88 FR 4708, Jan. 24, 2023]

§1066.425 Performing emission tests.

(a) See the standard-setting part for drive schedules. These are defined by a smooth fit of a specified speed vs. time sequence.

(b) The driver must attempt to follow the target schedule as closely as possible, consistent with the specifications in paragraph (b) of this section. Instantaneous speeds must stay within the following tolerances:

(1) The upper limit is 2.0 mi/hr higher than the highest point on the trace within 1.0 s of the given point in time.

(2) The lower limit is 2.0 mi/hr lower than the lowest point on the trace within 1.0 s of the given time.

(3) The same limits apply for vehicle operation without exhaust measurements, such as vehicle preconditioning and warm-up, except that the upper and lower limits for speed values are ±4.0 mi/hr. In addition, up to three occurrences of speed variations greater than the tolerance are acceptable for vehicle operation in which no exhaust emission standards apply, as long as they occur for less than 15 seconds on any occasion and are clearly documented as to the time and speed at that point of the driving schedule.

(4) Void the test if you do not maintain speed values as specified in this paragraph (b), except as allowed by this paragraph (b)(4). Speed variations (such as may occur during gear changes or braking spikes) may occur as follows, as long as such variations are clearly documented, including the time and speed values and the reason for the deviation:

(i) Speed variations greater than the specified limits are acceptable for up to 2.0 seconds on any occasion.

(ii) For vehicles that are not able to maintain acceleration as specified in §1066.415(e)(5), do not count the insufficient acceleration as being outside the specified limits.

(5) We may approve an alternate test cycle and cycle-validation criteria for vehicles that do not have enough power to follow the specified driving trace. The alternate driving specifications must be based on making best efforts to maintain acceleration and speed to follow the specified test cycle. We must approve these alternate driving specifications before you perform this testing.

(c) Figure 1 and Figure 2 of this section show the range of acceptable speed tolerances for typical points during testing. Figure 1 of this section is typical of portions of the speed curve that are increasing or decreasing throughout the 2-second time interval. Figure 2 of this section is typical of portions of the speed curve that include a maximum or minimum value.

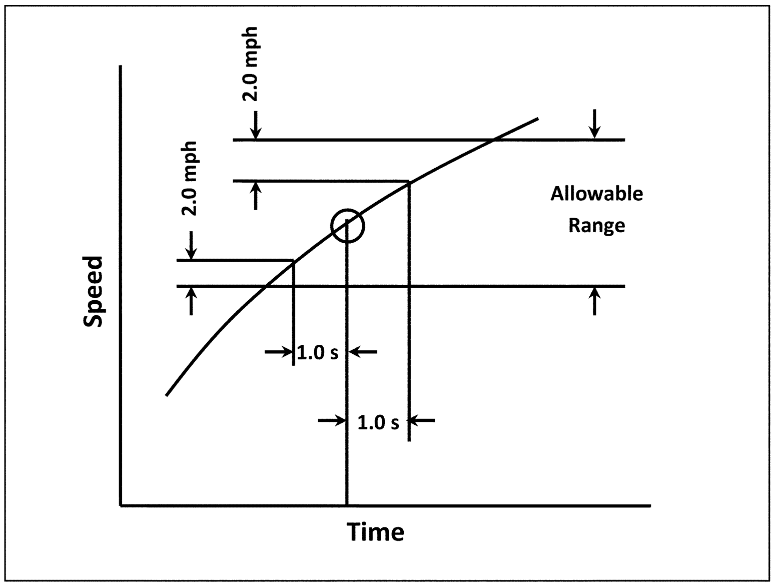


Figure 1 of § 1066.425—Example of the allowable ranges for the driver's trace

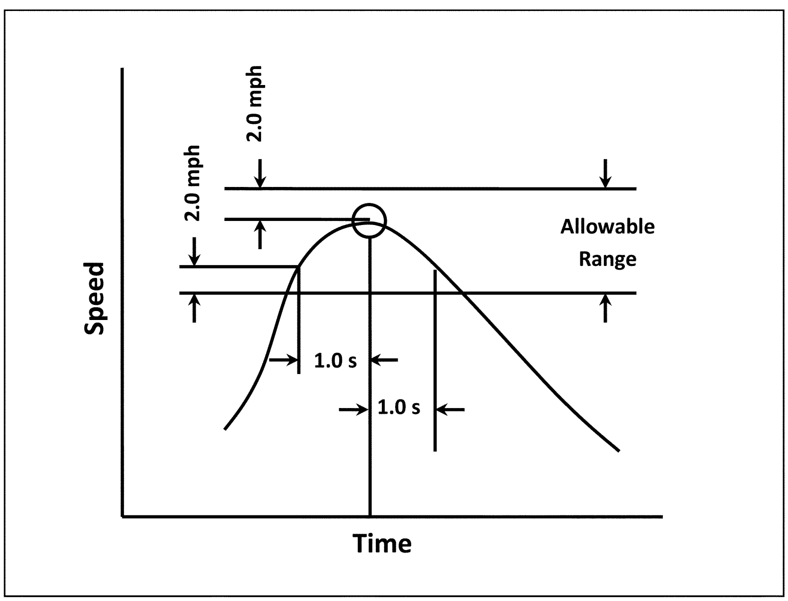


Figure 2 of § 1066.425—Example of the allowable ranges for the driver's trace

(d) Start testing as follows:

(1) If a vehicle is already running and warmed up, and starting is not part of the test cycle, operate the vehicle as follows:

(i) For transient test cycles, control vehicle speeds to follow a drive schedule consisting of a series of idles, accelerations, cruises, and decelerations.

(ii) For cruise test cycles, control the vehicle operation to match the speed of the first interval of the test cycle. Follow the instructions in the standard-setting part to determine how long to stabilize the vehicle during each interval, how long to sample emissions at each interval, and how to transition between intervals.

(2) If engine starting is part of the test cycle, start recording continuous data, turn on any electronic integrating devices, and start batch sampling before starting the engine. Initiate the driver's trace when the engine starts.

(e) Perform the following at the end of each test interval, except as specified in standard-setting part:

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

(2) Continue to operate all sampling and dilution systems to allow the response times to elapse. Then stop all sampling and recording, including background sampling. Finally, stop any integrating devices and indicate the end of the duty cycle in the recorded data.

(f) If testing involves engine shutdown followed by another test interval, start a timer for the vehicle soak when the engine shuts down. Turn off cooling fans, close the engine compartment cover (if applicable), and turn off the CVS or disconnect the exhaust tube from the vehicle's tailpipe(s) unless otherwise instructed in the standard-setting part. If testing is complete, disconnect the laboratory exhaust tubing from the vehicle's tailpipe(s) and drive the vehicle from the dynamometer.

(g) Take the following steps after emission sampling is complete:

(1) For any proportional batch sample, such as a bag sample or PM sample, verify that proportional sampling was maintained according to 40 CFR 1065.545. Void any samples that did not maintain proportional sampling according to those specifications.

(2) Place any used PM samples into covered or sealed containers and return them to the PM-stabilization environment. Follow the PM sample post-conditioning and total weighing procedures in 40 CFR 1065.595.

(3) As soon as practical after the interval or test cycle is complete, or optionally during the soak period if practical, perform the following:

(i) Begin drift check for all continuous gas analyzers as described in paragraph (g)(5) of this section and zero and span all batch gas analyzers as soon as practical before any batch sample analysis. You may perform this batch analyzer zero and span before the end of the test interval.

(ii) Analyze any conventional gaseous batch samples (HC, CH_4, CO, NO_X, and CO_2) no later than 30 minutes after a test interval is complete, or during the soak period if practical. Analyze background samples no later than 60 minutes after the test interval is complete.

(iii) Analyze nonconventional gaseous batch samples (including background), such as NMHCE, N_2O, or NMOG sampling with ethanol, as soon as practicable using good engineering judgment.

(4) If an analyzer operated above 100% of its range at any time during the test, perform the following steps:

(i) For batch sampling, re-analyze the sample using the lowest analyzer range that results in a maximum instrument response below 100%. Report the result from the lowest range from which the analyzer operates below 100% of its range.

(ii) For continuous sampling, repeat the entire test using the next higher analyzer range. If the analyzer again operates above 100% of its range, repeat the test using the next higher range. Continue to repeat the test until the analyzer consistently operates at less than 100% of its range. Keep records of any tests where the analyzer exceeds its range. We may consider these results to determine that the test vehicle exceeded an emission standard, consistent with good engineering judgment.

(5) After quantifying exhaust gases, verify drift as follows:

(i) For batch and continuous gas analyzers, record the mean analyzer value after stabilizing a zero gas to the analyzer. Stabilization may include time to purge the analyzer of any sample gas, plus any additional time to account for analyzer response.

(ii) Record the mean analyzer value after stabilizing the span gas to the analyzer. Stabilization may include time to purge the analyzer of any sample gas, plus any additional time to account for analyzer response.

(iii) Use these data to verify that analyzer drift does not exceed 2.0% of the analyzer full scale.

(h) Measure and record ambient pressure. Measure and record ambient temperature continuously to verify that it remains within the temperature range specified in §1066.420(c)(1) throughout the test. Also measure humidity if required, such as for correcting NO_X emissions, or meeting the requirements of §1066.420(d).

(i) [Reserved]

(j) For vehicles at or below 14,000 pounds GVWR, determine overall driver accuracy as follows:

(1) Compare the following drive-cycle metrics, based on measured vehicle speeds, to a reference value based on the target cycle that would have been generated by driving exactly to the target trace as described in SAE J2951 (incorporated by reference, see §1066.1010):

(i) Determine the Energy Economy Rating as described in Section 5.4 of SAE J2951.

(ii) Determine the Absolute Speed Change Rating as described in Section 5.5 of SAE J2951.

(iii) Determine the Inertia Work Rating as described in Section 5.6 of SAE J2951.

(iv) Determine the phase-weighted composite Energy Based Drive Metrics for the criteria specified in this paragraph (j)(1) as described in Section 5.7 of SAE J2951.

(2) The standard-setting part may require you to give us 10 Hz data to characterize both target and actual values for cycle energy. Calculate target values based on the vehicles speeds from the specified test cycle.

[79 FR 23823, Apr. 28, 2016, as amended at 81 FR 74203, Oct. 25, 2016; 89 FR 28212, Apr. 18, 2024]

Subpart F—Electric Vehicles and Hybrid Electric Vehicles

§ 1066.501 Overview.

Use the following procedures to test EVs and HEVs (including PHEVs):

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

(1) For all sizes of EV, follow SAE J1634 (incorporated by reference, see §1066.1010).

(2) For HEV at or below 14,000 pounds GVWR, follow SAE J1711 (incorporated by reference, see §1066.1010) except as described in this paragraph (a). Disregard provisions of SAE J1711 that differ from this part or the standard-setting part if they are not specific to HEV. Apply the following adjustments and clarifications to SAE J1711:

(i) If the procedure calls for charge-sustaining operation, start the drive with a State of Charge that is appropriate to ensure charge-sustaining operation for the duration of the drive. Take steps other than emission measurements to confirm that vehicles are in charge-sustaining mode for the duration of the drive.

(ii) You may use Appendix C of SAE J1711 for charge-sustaining tests to correct final fuel economy values, CO_2 emissions, and carbon-related exhaust emissions, but not to correct measured values for criteria pollutant emissions.

(iii) You may test subject to a measurement accuracy of ±0.3% of full scale in place of the measurement accuracy specified in Section 4.4 of SAE J1711.

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

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

(c) You may stop emission sampling anytime the engine is turned off, consistent with good engineering judgment. This is intended to allow for higher concentrations of dilute exhaust gases and more accurate measurements. Take steps to account for exhaust transport delay in the sampling system, and be sure to integrate over the actual sampling duration when determining V_{mix}.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9121, Feb. 19, 2015; 89 FR 28212, Apr. 18, 2024]

Subpart G—Calculations

§ 1066.601 Overview.

(a) This subpart describes calculations used to determine emission rates. See the standard-setting part and the other provisions of this part to determine which equations apply for your testing. This subpart describes how to—

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

(2) Perform calculations for calibrations and performance checks.

(3) Determine statistical values.

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

§ 1066.605 Mass-based and molar-based exhaust emission calculations.

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

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

(c) Perform the following sequence of preliminary calculations to correct recorded concentration measurements before calculating mass emissions in paragraphs (e) and (f) of this section:

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

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

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

(4) For vehicles at or below 14,000 pounds GVWR, calculate HC concentrations, including dilution air background concentrations, as described in this section, and as described in §1066.635 for NMOG. For emission testing of vehicles above 14,000 pounds GVWR, with fuels that contain 25% or more oxygenated compounds by volume, calculate THCE and NMHCE concentrations, including dilution air background concentrations, as described in 40 CFR part 1065, subpart I.

(5) Correct all gaseous concentrations for dilution air background as described in §1066.610.

(6) Correct NO_X emission values for intake-air humidity as described in §1066.615.

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

(d) Calculate g/mile emission rates using the following equation unless the standard-setting part specifies otherwise:

$$e_{[\text{emission}]} = \frac{m_{[\text{emission}]}}{D}$$

Eq. 1066.605-1

Where:

$e_{[\text{emission}]}$ = emission rate over the test interval.

$m_{[\text{emission}]}$ = emission mass over the test interval.

D = the measured driving distance over the test interval.

Example:

m_{NOx} = 0.3177 g

D_{HFET} = 10.19 miles

$$e_{NOx} = \frac{0.3177}{10.19} = 0.0312 \text{ g/mi}$$

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

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

Eq. 1066.605-2

Where:

$m_{[\text{emission}]}$ = emission mass over the test interval.

V_{mix} = total dilute exhaust volume over the test interval, corrected to standard reference conditions, and corrected for any volume removed for emission sampling and for any volume change from adding secondary dilution air.

$p_{[\text{emission}]}$ = density of the appropriate chemical species as given in § 1066.1005(f).

$x_{[\text{emission}]}$ = measured emission concentration in the sample, after dry-to-wet and background corrections.

c = 10^{-2} for emission concentrations in %, and 10^{-6} for emission concentrations in ppm.

Example:

V_{mix} = 170.878 m^3 (from paragraph (f) of this section)

ρ_{NOx} = 1913 g/m^3

x_{NOx} = 0.9721 ppm

$c = 10^{-6}$

$m_{NOx} = 170.878 \cdot 1913 \cdot 0.9721 \cdot 10^{-6} = 0.3177$ g

(f) Calculation of the emission mass of PM, m_{PM}, is dependent on how many PM filters you use, as follows:

(1) Except as otherwise specified in this paragraph (f), calculate m_{PM} using the following equation:

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

Eq. 1066.605-3

Where:

m_{PM} = mass of particulate matter emissions over the test interval, as described in §1066.815(b)(1), (2), and (3).

V_{mix} = total dilute exhaust volume over the test interval, corrected to standard reference conditions, and corrected for any volume removed for emission sampling and for any volume change from adding secondary dilution air. For partial-flow dilution systems, set V_{mix} equal to the total exhaust volume over the test interval, corrected to standard reference conditions.

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

V_{sdastd} = total volume of secondary dilution air sampled through the filter over the test interval, corrected to standard reference conditions. For partial-flow dilution systems, set V_{sdastd} equal to total dilution air volume over the test interval, corrected to standard reference conditions.

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

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

Example:

V_{mix} = 170.878 m^3 (from paragraph (g) of this section)

V_{PMstd} = 0.925 m^3 (from paragraph (g) of this section)

V_{sdastd} = 0.527 m^3 (from paragraph (g) of this section)

m_{PMfil} = 0.0000045 g

$m_{PMbkgnd}$ = 0.0000014 g

$$m_{PM} = \left(\frac{170.878}{0.925 - 0.527}\right) \cdot \left(0.0000045 - 0.0000014\right) = 0.00133 \text{ g}$$

(2) If you sample PM onto a single filter as described in §1066.815(b)(4)(i) or (b)(4)(ii) (for constant volume samplers), calculate m_{PM} using the following equation:

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

Eq. 1066.605-4

Where:

m_{PM} = mass of particulate matter emissions over the entire FTP.

V_{mix} = total dilute exhaust volume over the test interval, corrected to standard reference conditions, and corrected for any volume removed for emission sampling and for any volume change from adding secondary dilution air.

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

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

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

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

Example:

V_{mix} = 633.691 m^3

$V_{ct\text{-}PMstd}$ = 0.925 m^3

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

$V_{s\text{-}PMstd}$ = 1.967 m^3

$V_{s\text{-}sdastd}$ = 1.121 m^3

$V_{ht\text{-}PMstd}$ = 1.122 m^3

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

m_{PMfil} = 0.0000106 g

$m_{PMbkgnd}$ = 0.0000014 g

$$m_{PM} = \left(\frac{633.691}{\frac{(0.925-0.527)}{0.43} + (1.967-1.121) + \frac{(1.122-0.639)}{0.57}} \right) \cdot (0.0000106 - 0.0000014)$$

$m_{PM} = 0.00222$ g

(3) If you sample PM onto a single filter as described in § 1066.815(b)(4)(ii) (for partial flow dilution systems), calculate m_{PM} using the following equation:

$$m_{PM} = \left(\frac{\frac{0.43 \cdot V_{ct\text{-}exhstd}}{V_{ct\text{-}PMstd} - V_{ct\text{-}dilstd}} + \frac{V_{s\text{-}exhstd}}{V_{s\text{-}PMstd} - V_{s\text{-}dilstd}} + \frac{0.57 \cdot V_{ht\text{-}exhstd}}{V_{ht\text{-}PMstd} - V_{ht\text{-}dilstd}}}{3} \right) \cdot (m_{PMfil} - m_{PMbkgnd})$$

Eq. 1066.605-5

Where:

m_{PM} = mass of particulate matter emissions over the entire FTP.

$V_{[interval]\text{-}exhstd}$ = total engine exhaust volume over the test interval (ct = cold transient, s = stabilized, ht = hot transient), corrected to standard reference conditions, and corrected for any volume removed for emission sampling.

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

$V_{[interval]\text{-}dilstd}$ = total volume of dilution air over the test interval (ct = cold transient, s = stabilized, ht = hot transient), corrected to standard reference conditions and for any volume removed for emission sampling.

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

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

Example:

$V_{ct\text{-}exhstd} = 5.55\ m^3$
$V_{ct\text{-}PMstd} = 0.526\ m^3$
$V_{ct\text{-}dilstd} = 0.481\ m^3$
$V_{s\text{-}exhstd} = 9.53\ m^3$
$V_{s\text{-}PMstd} = 0.903\ m^3$
$V_{s\text{-}dilstd} = 0.857\ m^3$
$V_{ht\text{-}exhstd} = 5.54\ m^3$
$V_{ht\text{-}PMstd} = 0.527\ m^3$
$V_{ht\text{-}dilstd} = 0.489\ m^3$
$m_{PMfil} = 0.0000106$ g
$m_{PMbkgnd} = 0.0000014$ g

$$m_{PM} = \left(\frac{\frac{0.43 \cdot 5.55}{0.526-0.481} + \frac{9.53}{0.903-0.857} + \frac{0.57 \cdot 5.54}{0.527-0.489}}{3} \right) \cdot (0.0000106 - 0.0000014)$$

$m_{PM} = 0.00269$ g

(4) If you sample PM onto a single filter as described in § 1066.815(b)(5)(i) or (b)(5)(ii) (for constant volume samplers), calculate m_{PM} using the following equation:

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

Eq. 1066.605-6

Where:

m_{PM} = mass of particulate matter emissions over the entire FTP.

V_{mix} = total dilute exhaust volume over the test interval, corrected to standard reference conditions, and corrected for any volume removed for emission sampling and for any volume change from secondary dilution air.

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

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

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

m_{PMbkgnd} = mass of particulate matter on the background filter over the test interval.

Example:

V_{mix} = 972.121 m³

$V_{\text{ct-PMstd}}$ = 0.925 m³

$V_{\text{ct-sdastd}}$ = 0.529 m³

$V_{\text{cs-PMstd}}$ = 1.968 m³

$V_{\text{cs-sdastd}}$ = 1.123 m³

$V_{\text{ht-PMstd}}$ = 1.122 m³

$V_{\text{ht-sdastd}}$ = 0.641 m³

$V_{\text{hs-PMstd}}$ = 1.967 m³

$V_{\text{hs-sdastd}}$ = 1.121 m³

m_{PMfil} = 0.0000229 g

m_{PMbkgnd} = 0.0000014 g

$$m_{\mathrm{PM}}=\left(\frac{972.121}{\dfrac{(0.925-0.529)+(1.968-1.123)}{0.43}+\dfrac{(1.122-0.641)+(1.967-1.121)}{0.57}}\right)\cdot(0.0000229-0.0000014)$$

m_{PM} = 0.00401 g

(5) If you sample PM onto a single filter as described in § 1066.815(b)(5)(ii) (for partial flow dilution systems), calculate m_{PM} using the following equation:

$$m_{\mathrm{PM}}=\left(\frac{0.43\cdot\left(\dfrac{V_{\text{ct-exhstd}}+V_{\text{cs-exhstd}}}{V_{\text{ct-PMstd}}-V_{\text{ct-dilstd}}+V_{\text{cs-PMstd}}-V_{\text{cs-dilstd}}}\right)+0.57\cdot\left(\dfrac{V_{\text{ht-exhstd}}+V_{\text{hs-exhstd}}}{V_{\text{ht-PMstd}}-V_{\text{ht-dilstd}}+V_{\text{hs-PMstd}}-V_{\text{hs-dilstd}}}\right)}{2}\right)\cdot\left(m_{\mathrm{PMfil}}-m_{\mathrm{PMbkgnd}}\right)$$

Eq. 1066.605-7

Where:

m_{PM} = mass of particulate matter emissions over the entire FTP.

$V_{\text{[interval]-exhstd}}$ = total engine exhaust volume over the test interval (ct = cold transient, cs = cold stabilized, ht = hot transient, hs = hot stabilized), corrected to standard reference conditions, and corrected for any volume removed for emission sampling.

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

$V_{[interval]\text{-}dilstd}$ = total volume of dilution air over the test interval (ct = cold transient, cs = cold stabilized, ht = hot transient, hs = hot stabilized), corrected to standard reference conditions and for any volume removed for emission sampling.

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

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

Example:

$V_{ct\text{-}exhstd}$ = 5.55 m^3

$V_{ct\text{-}PMstd}$ = 0.526 m^3

$V_{ct\text{-}dilstd}$ = 0.481 m^3

$V_{cs\text{-}exhstd}$ = 9.53 m^3

$V_{cs\text{-}PMstd}$ = 0.903 m^3

$V_{cs\text{-}dilstd}$ = 0.857 m^3

$V_{ht\text{-}exhstd}$ = 5.54 m^3

$V_{ht\text{-}PMstd}$ = 0.527 m^3

$V_{ht\text{-}dilstd}$ = 0.489 m^3

$V_{hs\text{-}exhstd}$ = 9.54 m^3

$V_{hs\text{-}PMstd}$ = 0.902 m^3

$V_{hs\text{-}dilstd}$ = 0.856 m^3

m_{PMfil} = 0.0000229 g

$m_{PMbkgnd}$ = 0.0000014 g

$$m_{PM} = \left(\frac{0.43 \cdot \left(\frac{5.55 + 9.53}{0.526 - 0.481 + 0.903 - 0.857} \right) + 0.57 \cdot \left(\frac{5.54 + 9.54}{0.527 - 0.489 + 0.902 - 0.856} \right)}{2} \right) \cdot (0.0000229 - 0.0000014)$$

m_{PM} = 0.00266 g

(g) This paragraph (g) describes how to correct flow and flow rates to standard reference conditions and provides an example for determining V_{mix} based on CVS total flow and the removal of sample flow from the dilute exhaust gas. You may use predetermined nominal values for removed sample volumes, except for flows used for batch sampling.

(1) Correct flow and flow rates to standard reference conditions as needed using the following equation:

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

Eq. 1066.605-8

Where:

$V_{[flow]std}$ = total flow volume at the flow meter, corrected to standard reference conditions.

$V_{[flow]act}$ = total flow volume at the flow meter at test conditions.

p_{in} = absolute static pressure at the flow meter inlet, measured directly or calculated as the sum of atmospheric pressure plus a differential pressure referenced to atmospheric pressure.

T_{std} = standard temperature.

p_{std} = standard pressure.

T_{in} = temperature of the dilute exhaust sample at the flow meter inlet.

Example:

V_{PMact} = 1.071 m^3

p_{in} = 101.7 kPa

T_{std} = 293.15 K

p_{std} = 101.325 kPa

T_{in} = 340.5 K

$$V_{PMstd} = \frac{1.071 \cdot 101.7 \cdot 293.15}{101.325 \cdot 340.5} = 0.925 \text{ m}^3$$

(2) The following example provides a determination of V_{mix} based on CVS total flow and the removal of sample flow from one dilute exhaust gas analyzer and one PM sampling system that is utilizing secondary dilution. Note that your V_{mix} determination may vary from Eq. 1066.605–7 based on the number of flows that are removed from your dilute exhaust gas and whether your PM sampling system is using secondary dilution. For this example, V_{mix} is governed by the following equation:

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

Eq. 1066.605-9

Where:

V_{CVSstd} = total dilute exhaust volume over the test interval at the flow meter, corrected to standard reference conditions.

V_{gasstd} = total volume of sample flow through the gaseous emission bench over the test interval, corrected to standard reference conditions.

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

V_{sdastd} = total volume of secondary dilution air flow sampled through the filter over the test interval, corrected to standard reference conditions.

Example:

Using Eq. 1066.605–8:

V_{CVSstd} = 170.451 m^3, where V_{CVSact} = 170.721 m^3, p_{in} = 101.7 kPa, and T_{in} = 294.7 K

Using Eq. 1066.605–8:

V_{gasstd} = 0.028 m^3, where V_{gasact} = 0.033 m^3, p_{in} = 101.7 kPa, and T_{in} = 340.5 K

Using Eq. 1066.605–8:

V_{PMstd} = 0.925 m^3, where V_{PMact} = 1.071 m^3, p_{in} = 101.7 kPa, and T_{in} = 340.5 K

Using Eq. 1066.605–8:

V_{sdastd} = 0.527 m^3, where V_{sdaact} = 0.531 m^3, p_{in} = 101.7 kPa, and T_{in} = 296.3 K

V_{mix} = 170.451 + 0.028 + 0.925 − 0.527 = 170.878 m^3

(h) Calculate total flow volume over a test interval, $V_{[flow]}$, for a CVS or exhaust gas sampler as follows:

(1) *Varying versus constant flow rates.* The calculation methods depend on differentiating varying and constant flow, as follows:

(i) We consider the following to be examples of varying flows that require a continuous multiplication of concentration times flow rate: raw exhaust, exhaust diluted with a constant flow rate of dilution air, and CVS dilution with a CVS flow meter that does not have an upstream heat exchanger or electronic flow control.

(ii) We consider the following to be examples of constant exhaust flows: CVS diluted exhaust with a CVS flow meter that has an upstream heat exchanger, an electronic flow control, or both.

(2) *Continuous sampling.* For continuous sampling, you must frequently record a continuously updated flow signal. This recording requirement applies for both varying and constant flow rates.

(i) *Varying flow rate.* If you continuously sample from a varying exhaust flow rate, calculate $V_{[flow]}$ using the following equation:

$$V_{[\text{flow}]} = \sum_{i=1}^{N} \dot{Q}_i \cdot \Delta t$$

Eq. 1066.605-10

Where:

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

Eq. 1066.605–11

Example:

$N = 505$

$\dot{Q}_{CVS1} = 0.276$ m³/s

$\dot{Q}_{CVS2} = 0.294$ m³/s

$f_{record} = 1$ Hz

Using Eq. 1066.605–11:

$\Delta t = 1/1 = 1$ s

$V_{CVS} = (0.276 + 0.294 + \dot{Q}_{CVS505}) \cdot 1$

$V_{CVS} = 170.721$ m³

(ii) *Constant flow rate.* If you continuously sample from a constant exhaust flow rate, use the same calculation described in paragraph (h)(2)(i) of this section or calculate the mean flow recorded over the test interval and treat the mean as a batch sample, as described in paragraph (h)(3)(ii) of this section.

(3) *Batch sampling.* For batch sampling, calculate total flow by integrating a varying flow rate or by determining the mean of a constant flow rate, as follows:

(i) *Varying flow rate.* If you proportionally collect a batch sample from a varying exhaust flow rate, integrate the flow rate over the test interval to determine the total flow from which you extracted the proportional sample, as described in paragraph (h)(2)(i) of this section.

(ii) *Constant flow rate.* If you batch sample from a constant exhaust flow rate, extract a sample at a proportional or constant flow rate and calculate $V_{[flow]}$ from the flow from which you extract the sample by multiplying the mean flow rate by the time of the test interval using the following equation:

$$V_{[flow]} = \overline{\dot{Q}} \cdot \Delta t$$

Eq. 1066.605-12

Example:

$\overline{\dot{Q}}_{CVS} = 0.338$ m³/s

$\Delta t = 505$ s

$V_{CVS} = 0.338 \cdot 505$

$V_{CVS} = 170.69$ m³

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9121, Feb. 19, 2015; 81 FR 74203, Oct. 25, 2016; 86 FR 34583, June 29, 2021]

§ 1066.610 Dilution air background correction.

(a) Correct the emissions in a gaseous sample for background using the following equation:

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

Eq. 1066.610-1

Where:

$x_{[emission]dexh}$ = measured emission concentration in dilute exhaust (after dry-to-wet correction, if applicable).

$x_{[emission]bkgnd}$ = measured emission concentration in the dilution air (after dry-to-wet correction, if applicable).

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

Example:

$x_{NOxdexh} = 1.08305$ ppm

$x_{NOxbkgnd} = 0.12456$ ppm

$DF = 9.14506$

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

(b) Except as specified in paragraph (c) of this section, determine the dilution factor, *DF*, over the test interval using the following equation:

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

Eq. 1066.610-2

Where:

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

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

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

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

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

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

Example:

x_{CO2} = 1.456 % = 0.01456

x_{NMHC} = 0.84 ppm = 0.00000084

x_{CH4} = 0.26 ppm = 0.00000026

x_{CO} = 80.4 ppm = 0.0000804

α = 1.92

β = 0.03

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

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

$$DF = \frac{V_{dexhstd}}{V_{exhstd}}$$

Eq. 1066.610-3

Where:

$V_{dexhstd}$ = total dilute exhaust volume sampled over the test interval, corrected to standard reference conditions.

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

Example:

$V_{dexhstd}$ = 170.9 m^3

V_{exhstd} = 15.9 m^3

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

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

$$DF_{\mathrm{w}} = \frac{\sum_{i=1}^{N} t_i}{\sum_{i=1}^{N} \frac{1}{DF_i} \cdot t_i}$$

Eq. 1066.610-4

Where:

N = number of test intervals

i = test interval number

t = duration of the test interval

DF = dilution factor over the test interval

Example:

N = 3

DF_1 = 14.40

t_1 = 505 s

DF_2 = 24.48

t_2 = 867 s

DF_3 = 17.28

t_3 = 505 s

$$DF_{\mathrm{w}} = \frac{505 + 867 + 505}{\left(\frac{1}{14.40} \cdot 505\right) + \left(\frac{1}{24.48} \cdot 867\right) + \left(\frac{1}{17.28} \cdot 505\right)} = 18.82$$

[79 FR 23823, Apr. 28, 2014, as amended at 86 FR 34583, June 29, 2021]

§ 1066.615 NO_X intake-air humidity correction.

You may correct NO_X emissions for intake-air humidity as described in this section if the standard-setting part allows it. See § 1066.605(c) for the proper sequence for applying the NO_X intake-air humidity correction.

(a) For vehicles at or below 14,000 pounds GVWR, apply a correction for vehicles with reciprocating engines operating over specific test cycles as follows:

(1) Calculate a humidity correction using a time-weighted mean value for ambient humidity over the test interval. Calculate absolute ambient humidity, H, using the following equation:

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

Eq. 1066.615-1

Where:

M_{H2O} = molar mass of H_2O.

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

RH = relative humidity of ambient air

M_{air} = molar mass of air.

p_{atmos} = atmospheric pressure.

Example:

M_{H2O} = 18.01528 g/mol

p_d = 2.93 kPa

RH = 37.5% = 0.375
M_{air} = 28.96559 g/mol
p_{atmos} = 96.71 kPa

$$H = \frac{1000 \cdot 18.01528 \cdot 2.93 \cdot 0.375}{28.96559 \cdot (96.71 - 2.93 \cdot 0.375)} = 7.14741 \text{ g } H_2O \text{ vapor/kg dry air}$$

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

$$x_{NOxcor} = x_{NOx} \cdot \frac{H_s}{1 - 0.0329 \cdot (H - 10.71)}$$ Eq. 1066.615-2

Where:

χ_{NOx} = measured NO_X emission concentration in the sample, after dry-to-wet and background corrections.

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

H = ambient humidity, as determined in paragraph (a)(1) of this section.

Example:

H = 7.14741 g H_2O vapor/kg dry air time weighted over the FTP test cycle

χ_{NOx} = 1.21 ppm

$$x_{NOxcor} = 1.21 \cdot \frac{1}{1 - 0.0329 \cdot (7.14741 - 10.71)} = 1.08305 \text{ ppm}$$

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

[80 FR 9121, Feb. 19, 2015, as amended at 81 FR 74207, Oct. 25, 2016]

§ 1066.620 Removed water correction.

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

§ 1066.625 Flow meter calibration calculations.

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

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

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

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

Eq. 1066.625-1

Where:

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

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

p_{std} = standard pressure = 101.325 kPa.

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

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

T_{std} = standard temperature = 293.15 K.

Example:

$\bar{\dot{V}}_{ref}$ = 0.1651 m³/s

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

p_{std} = 101.325 kPa

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

$\bar{P}_{in}$ = 98.290 kPa

T_{std} = 293.15 K

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

V_{rev} = 0.00866 m³/r

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

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

Eq. 1066.625-2

Where:

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

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

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

Example:

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

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

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

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

K_s = 0.006700 s/r

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

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

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

TABLE 1 OF § 1066.625—EXAMPLE OF PDP CALIBRATION DATA

$\bar{f}_{nPDP}$ (revolution/s)	a_1 (m³/s)	a_0 (m³/revolution)
12.6	0.841	0.056
16.5	0.831	−0.013
20.9	0.809	0.028
23.4	0.788	−0.061

(6) For each speed at which you operate the PDP, use the appropriate regression equation from this paragraph (a) to calculate flow rate during emission testing as described in § 1066.630.

(b) *SSV calibration*. The equations governing SSV flow assume one-dimensional isentropic inviscid flow of an ideal gas. Paragraph (b)(2)(iv) of this section describes other assumptions that may apply. If good engineering judgment dictates that you account for gas compressibility, you may either use an appropriate equation of state to determine values of Z as a function of measured pressure and temperature, or you may develop your own calibration equations based on good engineering judgment. Note that the equation for the flow coefficient, C_f, is based on the ideal gas assumption that the isentropic exponent, γ, is equal to the ratio of specific heats, C_p/C_v. If good engineering judgment dictates using a real gas isentropic exponent, you may either use an appropriate equation of state to determine values of γ as a function of measured pressure and temperature, or you may develop your own calibration equations based on good engineering judgment.

(1) Calculate volume flow rate at standard reference conditions, $\dot{V}_{std}$, as follows

$$\dot{V}_{std} = C_d \cdot C_f \cdot \frac{A_t \cdot R \cdot p_{in} \cdot T_{std}}{p_{std} \cdot \sqrt{Z \cdot M_{mix} \cdot R \cdot T_{in}}}$$

Eq. 1066.625-3

Where:

C_d = discharge coefficient, as determined in paragraph (b)(2)(i) of this section.

C_f = flow coefficient, as determined in paragraph (b)(2)(ii) of this section.

A_t = cross-sectional area at the venturi throat.

R = molar gas constant.

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

T_{std} = standard temperature.

p_{std} = standard pressure.

Z = compressibility factor.

M_{mix} = molar mass of gas mixture.

T_{in} = absolute temperature at the venturi inlet.

(2) Perform the following steps to calibrate an SSV flow meter:

(i) Using the data collected in § 1066.140, calculate C_d for each flow rate using the following equation:

$$C_d = \dot{V}_{ref} \cdot \frac{p_{std} \cdot \sqrt{Z \cdot M_{mix} \cdot R \cdot T_{in}}}{C_f \cdot A_t \cdot R \cdot p_{in} \cdot T_{std}}$$

Eq. 1066.625-4

Where:

$\bar{\dot{V}}_{ref}$ = measured volume flow rate from the reference flow meter.

(ii) Use the following equation to calculate C_f for each flow rate:

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

Where:

γ = isentropic exponent. For an ideal gas, this is the ratio of specific heats of the gas mixture, C_p/C_v.

r = pressure ratio, as determined in paragraph (b)(2)(iii) of this section.

β = ratio of venturi throat diameter to inlet diameter.

(iii) Calculate r using the following equation:

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

Eq. 1066.625-6

Where:

Δp = differential static pressure, calculated as venturi inlet pressure minus venturi throat pressure.

(iv) You may apply any of the following simplifying assumptions or develop other values as appropriate for your test configuration, consistent with good engineering judgment:

(A) For raw exhaust, diluted exhaust, and dilution air, you may assume that the gas mixture behaves as an ideal gas ($Z = 1$).

(B) For raw exhaust, you may assume $\gamma = 1.385$.

(C) For diluted exhaust and dilution air, you may assume $\gamma = 1.399$.

(D) For diluted exhaust and dilution air, you may assume the molar mass of the mixture, M_{mix}, is a function only of the amount of water in the dilution air or calibration air, as follows:

$$M_{mix} = M_{air} \cdot (1 - x_{H2O}) + M_{H_2O} \cdot x_{H2O}$$

Eq. 1066.625-7

Where:

M_{air} = molar mass of dry air.x_{H2O} = amount of H_2O in the dilution air or calibration air, determined as described in 40 CFR 1065.645.

M_{H2O} = molar mass of water.

Example:

M_{air} = 28.96559 g/mol

x_{H2O} = 0.0169 mol/mol

M_{H2O} = 18.01528 g/mol

M_{mix} = 28.96559 · (1 − 0.0169) + 18.01528 · 0.0169

M_{mix} = 28.7805 g/mol

(E) For diluted exhaust and dilution air, you may assume a constant molar mass of the mixture, M_{mix}, for all calibration and all testing if you control the amount of water in dilution air and in calibration air, as illustrated in the following table:

TABLE 2 OF § 1066.625—EXAMPLES OF DILUTION AIR AND CALIBRATION AIR DEWPOINTS AT WHICH YOU MAY ASSUME A CONSTANT M_{mix}

If calibration T_{dew} (°C) is . . .	assume the following constant M_{mix} (g/mol) . . .	for the following ranges of T_{dew} (°C) during emission tests [a]
≤0	28.96559	≤18
0	28.89263	≤21
5	28.86148	≤22
10	28.81911	≤24
15	28.76224	≤26
20	28.68685	−8 to 28
25	28.58806	12 to 31
30	28.46005	23 to 34

[a] The specified ranges are valid for all calibration and emission testing over the atmospheric pressure range (80.000 to 103.325) kPa.

(v) The following example illustrates the use of the governing equations to calculate C_d of an SSV flow meter at one reference flow meter value:

$\bar{\dot{V}}_{ref}$ = 2.395 m³/s

Z = 1

M_{mix} = 28.7805 g/mol = 0.0287805 kg/mol

R = 8.314472 J/(mol·K) = 8.314472 (m²·kg)/(s²·mol·K)

T_{in} = 298.15 K

A_t = 0.01824 m²

p_{in} = 99.132 kPa = 99132 Pa = 99132 kg/(m·s²)

γ = 1.399

β = 0.8

Δp = 7.653 kPa

$$r = 1 - \frac{2.312}{99.132} = 0.922$$

$$C_f = \left[\frac{2 \cdot 1.399 \cdot \left(0.922^{\frac{1.399-1}{1.399}} - 1\right)}{(1.399-1) \cdot \left(0.8^4 - 0.922^{\frac{-2}{1.399}}\right)} \right]^{\frac{1}{2}}$$

C_f = 0.472

$$C_d = 2.395 \cdot \frac{101325 \cdot \sqrt{1 \cdot 0.0287805 \cdot 8.314472 \cdot 298.15}}{0.472 \cdot 0.01824 \cdot 8.314472 \cdot 99132 \cdot 293.15}$$

C_d = 0.985

(vi) Calculate the Reynolds number, $Re^{\#}$, for each reference flow rate at standard conditions, $\bar{\dot{V}}_{refstd}$, using the throat diameter of the venturi, d_t, and the air density at standard conditions, ρ_{std}. Because the dynamic viscosity, μ, is needed to compute $Re^{\#}$, you may use your own fluid viscosity model to determine μ for your calibration gas (usually air), using good engineering judgment. Alternatively, you may use the

Sutherland three-coefficient viscosity model to approximate μ, as shown in the following sample calculation for $Re^{\#}$:

$$Re^{\#} = \frac{4 \cdot \rho_{\text{std}} \cdot \dot{V}_{\text{refstd}}}{\pi \cdot d_{\text{t}} \cdot \mu}$$

Eq. 1066.625-8

Where, using the Sutherland three-coefficient viscosity model:

$$\mu = \mu_0 \cdot \left(\frac{T_{\text{in}}}{T_0}\right)^{\frac{3}{2}} \cdot \left(\frac{T_0 + S}{T_{\text{in}} + S}\right)$$

Eq. 1066.625-9

Where:

μ_0 = Sutherland reference viscosity.

T_0 = Sutherland reference temperature.

S = Sutherland constant.

TABLE 3 OF § 1066.625—SUTHERLAND THREE-COEFFICIENT VISCOSITY MODEL PARAMETERS

Gas [1]	μ_0	T_0	S	Temperature range within ±2% error [2]	Pressure limit [2]
	kg/(m·s)	K	K	K	kPa
Air	$1.716 \cdot 10^{-5}$	273	111	170 to 1900	≤1800.
CO_2	$1.370 \cdot 10^{-5}$	273	222	190 to 1700	≤3600.
H_2O	$1.12 \cdot 10^{-5}$	350	1064	360 to 1500	≤10000.
O_2	$1.919 \cdot 10^{-5}$	273	139	190 to 2000	≤2500.
N_2	$1.663 \cdot 10^{-5}$	273	107	100 to 1500	≤1600.

[1] Use tabulated parameters only for the pure gases, as listed. Do not combine parameters in calculations to calculate viscosities of gas mixtures.

[2] The model results are valid only for ambient conditions in the specified ranges.

Example:

$\mu_0 = 1.716 \cdot 10^{-5}$ kg/(m·s)

T_0 = 273 K

S = 111 K

$$\mu = 1.716 \cdot 10^{-5} \cdot \left(\frac{298.15}{273}\right)^{\frac{3}{2}} \cdot \left(\frac{273+111}{298.15+111}\right)$$

$\mu = 1.838 \cdot 10^{-5}$ kg/(m·s)

T_{in} = 298.15 K

d_{t} = 152.4 mm = 0.1524 m

ρ_{std} = 1.1509 kg/m^3

$$Re^{\#} = \frac{4 \cdot 1.1964 \cdot 2.395}{3.14159 \cdot 0.1524 \cdot 1.838 \cdot 10^{-5}}$$

$Re^{\#} = 1.3027 \cdot 10^6$

(vii) Calculate ρ using the following equation:

$$\rho_{\text{std}} = \frac{p_{\text{std}} \cdot MW_{\text{mix}}}{R \cdot T_{\text{std}}}$$

Eq. 1066.625-10

Example:

$$\rho_{\text{std}} = \frac{101325 \cdot 0.0287805}{8.314472 \cdot 293.15}$$

$\rho_{\text{std}} = 1.1964$ kg/m^3

(viii) Create an equation for C_d as a function of $Re^{\#}$, using paired values of the two quantities. The equation may involve any mathematical expression, including a polynomial or a power series. The following equation is an example of a commonly used mathematical expression for relating C_d and $Re^{\#}$:

$$C_{\text{d}} = a_0 - a_1 \cdot \sqrt{\frac{10^6}{Re^{\#}}}$$

Eq. 1066.625-11

(ix) Perform a least-squares regression analysis to determine the best-fit coefficients for the equation and calculate *SEE* as described in 40 CFR 1065.602.

(x) If the equation meets the criterion of $SEE \leq 0.5\% \cdot C_{\text{dmax}}$, you may use the equation for the corresponding range of $Re^{\#}$, as described in § 1066.630(b).

(xi) If the equation does not meet the specified statistical criteria, you may use good engineering judgment to omit calibration data points; however, you must use at least seven calibration data points to demonstrate that you meet the criterion. For example, this may involve narrowing the range of flow rates for a better curve fit.

(xii) Take corrective action if the equation does not meet the specified statistical criterion even after omitting calibration data points. For example, select another mathematical expression for the C_d versus $Re^{\#}$ equation, check for leaks, or repeat the calibration process. If you must repeat the calibration process, we recommend applying tighter tolerances to measurements and allowing more time for flows to stabilize.

(xiii) Once you have an equation that meets the specified statistical criterion, you may use the equation only for the corresponding range of $Re^{\#}$.

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

(1) To determine K_v for a single venturi or a combination of venturis, perform the following steps:

(i) Calculate an individual K_v for each calibration set point for each restrictor position using the following equation:

$$K_v = \frac{\bar{\dot{V}}_{\text{refstd}} \cdot \sqrt{\bar{T}_{\text{in}}}}{\bar{p}_{\text{in}}}$$

Eq. 1066.625-12

Where:

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

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

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

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

(iii) If the standard deviation of all the K_v values is less than or equal to 0.3% of the mean K_v, use the mean K_v in Eq. 1066.630–7, and use the CFV only up to the highest venturi pressure ratio, r, measured during calibration using the following equation:

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

Eq. 1066.625-13

Where:

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

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

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

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

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

(vii) If the standard deviation of the remaining K_v values is less than or equal to 0.3% of the mean of the remaining K_v, use that mean K_v in Eq 1066.630–7, and use the CFV values only up to the highest r associated with the remaining K_v.

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

(2) During exhaust emission tests, monitor sonic flow in the CFV by monitoring r. Based on the calibration data selected to meet the standard deviation criterion in paragraphs (c)(1)(iv) and (vii) of this section, in which K_v is constant, select the data values associated with the calibration point with the lowest absolute venturi inlet pressure to determine the r limit. Calculate r during the exhaust emission test using Eq. 1066.625–8 to demonstrate that the value of r during all emission tests is less than or equal to the r limit derived from the CFV calibration data.

[79 FR 23823, Apr. 28, 2016, as amended at 81 FR 74208, Oct. 25, 2016]

§ 1066.630 PDP, SSV, and CFV flow rate calculations.

This section describes the equations for calculating flow rates from various flow meters. After you calibrate a flow meter according to § 1066.625, use the calculations described in this section to calculate flow during an emission test. Calculate flow according to 40 CFR 1065.642 instead if you calculate emissions based on molar flow rates.

(a) *PDP*. (1) Based on the speed at which you operate the PDP for a test interval, select the corresponding slope, a_1, and intercept, a_0, as determined in § 1066.625(a), to calculate PDP flow rate, $\dot{v}$, as follows:

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

Eq. 1066.630-1

Where:

f_{nPDP} = pump speed.

V_{rev} = PDP volume pumped per revolution, as determined in paragraph (a)(2) of this section.

T_{std} = standard temperature = 293.15 K.

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

T_{in} = absolute temperature at the PDP inlet.

p_{std} = standard pressure = 101.325 kPa.

(2) Calculate V_{rev} using the following equation:

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

Eq. 1066.630–2

Where:

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

Example:

a_1 = 0.8405 m^3/s

f_{nPDP} = 12.58 r/s

p_{out} = 99.950 kPa

p_{in} = 98.575 kPa

a_0 = 0.056 m^3/r

T_{in} = 323.5 K

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

$$V_{\mathrm{rev}} = 0.063\ \mathrm{m^3/r}$$

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

$$\dot{V} = 0.7079\ \mathrm{m^3/s}$$

(b) *SSV*. Calculate SSV flow rate, $\dot{v}$, as follows:

$$\dot{V} = C_{\mathrm{d}} \cdot C_{\mathrm{f}} \cdot \frac{A_{\mathrm{t}} \cdot R \cdot p_{\mathrm{in}} \cdot T_{\mathrm{std}}}{p_{\mathrm{std}} \cdot \sqrt{Z \cdot M_{\mathrm{mix}} \cdot R \cdot T_{\mathrm{in}}}}$$

Eq. 1066.630-3

Where:

C_{d} = discharge coefficient, as determined based on the C_{d} versus $Re^{\#}$ equation in § 1066.625(b)(2)(viii).

C_{f} = flow coefficient, as determined in § 1066.625(b)(2)(ii).

A_{t} = venturi throat cross-sectional area.

R = molar gas constant.

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

T_{std} = standard temperature.

p_{std} = standard pressure.

Z = compressibility factor.

M_{mix} = molar mass of gas mixture.

T_{in} = absolute temperature at the venturi inlet.

Example:

C_{d} = 0.890

C_{f} = 0.472

A_{t} = 0.01824 m^2

R = 8.314472 J/(mol·K) = 8.314472 (m^2·kg)/(s^2·mol·K)

p_{in} = 98.496 kPa

T_{std} = 293.15 K

p_{std} = 101.325 kPa

Z = 1

M_{mix} = 28.7789 g/mol = 0.0287789 kg/mol

T_{in} = 296.85 K

$$\dot{V} = 0.89 \cdot 0.472 \cdot \frac{0.01824 \cdot 8.314472 \cdot 98.496 \cdot 293.15}{101.325 \cdot \sqrt{1 \cdot 0.0287805 \cdot 8.314472 \cdot 296.85}}$$

$\dot{V}$ = 2.155 m^3/s

(c) *CFV*. If you use multiple venturis and you calibrated each venturi independently to determine a separate calibration coefficient, K_{v}, for each venturi, calculate the individual volume flow rates through each venturi and sum all their flow rates to determine CFV flow rate, $\dot{V}$. If you use multiple venturis and you calibrated venturis in combination, calculate $\dot{V}$ using the K_{v} that was determined for that combination of venturis.

(1) To calculate $\dot{V}$ through one venturi or a combination of venturis, use the mean K_v you determined in §1066.625(c) and calculate $\dot{V}$ as follows:

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

Eq. 1066.630-4

Where:

K_v = flow meter calibration coefficient.
T_{in} = temperature at the venturi inlet.
p_{in} = absolute static pressure at the venturi inlet.

Example:

K_v = 0.074954 $m^3 \cdot K^{0.5}/(kPa \cdot s)$
p_{in} = 99.654 kPa
T_{in} = 353.15 K

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

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

(2) [Reserved]

[81 FR 74211, Oct. 25, 2016, as amended at 89 FR 28212, Apr. 18, 2024]

§ 1066.635 NMOG determination.

For vehicles subject to an NMOG standard, determine NMOG as described in paragraph (a) of this section. Except as specified in the standard-setting part, you may alternatively calculate NMOG results based on measured NMHC emissions as described in paragraphs (c) through (f) of this section. Note that references to the FTP in this section apply for testing over the FTP test cycle at any ambient temperature.

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

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

Eq. 1066.635-1

Where:

m_{NMHC} = the mass of NMHC and all oxygenated hydrocarbon (OHC) in the exhaust, as determined using Eq. 1066.605–2. Calculate NMHC mass based on ρ_{NMHC}.
ρ_{NMHC} = the effective C_1-equivalent density of NMHC as specified in §1066.1005(f).
m_{OHCi} = the mass of oxygenated species i in the exhaust calculated using Eq. 1066.605–2.
ρ_{OCHi} = the C_1-equivalent density of oxygenated species i.

$RF_{OHCi[THC\text{-}FID]}$ = the response factor of a THC-FID to oxygenated species i relative to propane on a C_1-equivalent basis as determined in 40 CFR 1065.845.

(b) The following example shows how to determine NMOG as described in paragraph (a) of this section for (OHC) compounds including ethanol (C_2H_5OH), methanol (CH_3OH), acetaldehyde (C_2H_4O), and formaldehyde (CH_2O) as C_1-equivalent concentrations:

m_{NMHC} = 0.0125 g
m_{CH3OH} = 0.0002 g
m_{C2H5OH} = 0.0009 g
m_{CH2O} = 0.0001 g
m_{C2H4O} = 0.00005 g
$RF_{CH3OH[THC\text{-}FID]}$ = 0.63
$RF_{C2H5OH[THC\text{-}FID]}$ = 0.75
$RF_{CH2O[THC\text{-}FID]}$ = 0.00
$RF_{C2H4O[THC\text{-}FID]}$ = 0.50
$\rho_{NMHC\text{-}liq}$ = 576.816 g/m³
ρ_{CH3OH} = 1332.02 g/m³
ρ_{C2H5OH} = 957.559 g/m³
ρ_{CH2O} = 1248.21 g/m³
ρ_{C2H4O} = 915.658 g/m³

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

$$0.0002 + 0.0009 + 0.0001 + 0.00005$$

$$m_{\text{NMOG}} = 0.013273$$

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

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

$$e_{\text{NMOGh}} = e_{\text{NMHCh}} \cdot 1.03$$

Eq. 1066.635-2

Where:

e_{NMOGh} = mass emission rate of NMOG from the hot-running test cycle.

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

Example:

e_{NMHCh} = 0.025 g/mi

e_{NMOGh} = 0.025 · 1.03 = 0.026 g/mi

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

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

Eq. 1066.635-3

Where:

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

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

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

Example:

$e_{NMHCcomp}$ = 0.025 g/mi

VP_{EtOH} = 10.1%

$e_{NMOGcomp} = 0.025 \cdot (1.0302 + 0.0071 \cdot 10.1) = 0.0275$ g/mi

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

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

Eq. 1066.635-4

Where:

$e_{NMOG\text{–}FTPct}$ = mass emission rate of NMOG from the transient portion of the FTP cold-start test (generally known as bag 1).

$e_{NMHC\text{–}FTPct}$ = mass emission rate of NMHC from the transient portion of the FTP cold-start test (bag 1), calculated using $\rho_{NMHC\text{-}liq}$.

Example:

$e_{NMHC\text{–}FTPct}$ = 0.052 g/mi

VP_{EtOH} = 10.1%

$e_{NMOG\text{–}FTPct} = 0.052 \cdot (1.0246 + 0.0079 \cdot 10.1) = 0.0574$ g/mi

(4) You may determine NMOG for the stabilized portion of the FTP test for either the cold-start test or the hot-start test (bag 2 or bag 4) for use in fuel economy and CREE calculations based on the corresponding NMHC emission rate and the volume percent of ethanol in the fuel using the following equation:

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

Eq. 1066.635-5

Where:

$e_{NMOG\text{–}FTPcs\text{-}hs}$ = mass emission rate of NMOG from the stabilized portion of the FTP test (bag 2 or bag 4).

$e_{NMHC\text{–}FTPcs\text{-}hs}$ = mass emission rate of NMHC from the stabilized portion of the FTP test (bag 2 or bag 4), calculated using $\rho_{NMHC\text{-}liq}$.

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

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

Eq. 1066.635-6

Where:

$e_{NMOG-FTPht}$ = mass emission rate of NMOG from the transient portion of the FTP hot-start test (bag 3).

$e_{NMHC-FTPht}$ = mass emission rate of NMHC from the transient portion of the FTP hot-start test (bag 3), calculated using $\rho_{NMHC\text{-}liq}$.

(6) For PHEVs, you may determine NMOG based on testing over one full UDDS using Eq. 1066.635–3.

(d) You may take the following alternative steps when determining fuel economy and CREE under 40 CFR part 600 for testing with ethanol-gasoline blends that have up to 25% ethanol by volume:

(1) Calculate NMOG by test interval using Eq. 1066.635–3 for individual bag measurements from the FTP.

(2) For HEVs, calculate NMOG for two-bag FTPs using Eq. 1066.635–3 as described in 40 CFR 600.114.

(e) We consider NMOG values for diesel-fueled vehicles, CNG-fueled vehicles, LNG-fueled vehicles, and LPG-fueled vehicles to be equivalent to NMHC emission values for all test cycles.

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

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9122, Feb. 19, 2015; 81 FR 74212, Oct. 25, 2016; 89 FR 28212, Apr 18, 2024]

§ 1066.695 Data requirements.

Record information for each test as follows:

(a) Test number.

(b) A brief description of the test vehicle (or other system/device tested).

(c) Date and time of day for each part of the test sequence.

(d) Test results. Also include a validation of driver accuracy as described in § 1066.425(j).

(e) Driver and equipment operators.

(f) Vehicle information as applicable, including identification number, model year, applicable emission standards (including bin standards or family emission limits, as applicable), vehicle model, vehicle class, test group, durability group, engine family, evaporative/refueling emission family, basic engine description (including displacement, number of cylinders, turbocharger/supercharger used, and catalyst type), fuel system (type of fuel injection and fuel tank capacity and location), engine code, GVWR, applicable test weight, inertia weight class, actual curb weight at zero miles, actual road load at 50 mi/hr, transmission class and configuration, axle ratio, odometer reading, idle rpm, and measured drive wheel tire pressure.

(g) Dynamometer identification, inertia weight setting, indicated power absorption setting, and records to verify compliance with the driving distance and cycle-validation criteria as calculated from measured roll or shaft revolutions.

(h) Analyzer bench identification, analyzer ranges, recordings of analyzer output during zero, span, and sample readings.

(i) Associate the following information with the test record: test number, date, vehicle identification, vehicle and equipment operators, and identification of the measurements recorded.

(j) Test cell barometric pressure and humidity. You may use a central laboratory barometer if the barometric pressure in each test cell is shown to be within ±0.1% of the barometric pressure at the central barometer location.

(k) Records to verify compliance with the ambient temperature requirements throughout the test procedure and records of fuel temperatures during the running loss test.

(l) [Reserved]

(m) For CVS systems, record dilution factor for each test interval and the following additional information:

(1) For CFV and SSV testing, V_{mix} for each interval of the exhaust test.

(2) For PDP testing, test measurements required to calculate V_{mix} for each test interval.

(n) The humidity of the dilution air, if you remove H_2O from an emission sample before measurement.

(o) Temperature of the dilute exhaust mixture and secondary dilution air (in the case of a double-dilution system) at the inlet to the respective gas meter or flow instrumentation used for PM sampling. Determine minimum values, maximum values, mean values, and percent of time outside of the tolerance over each test interval.

(p) The maximum exhaust gas temperature over the course of the test interval within 20 cm upstream or downstream of PM sample media.

(q) If applicable, the temperatures of the heated FID, the gas in the heated sample line, and the heated filter. Determine minimum values, maximum values, average values, and percent of time outside of the tolerance over each test interval.

(r) Gas meter or flow measurement instrumentation readings used for batch sampling over each test interval. Determine minimum, maximum, and average values over each test interval.

(s) The stabilized pre-test weight and post-test weight of each particulate sample media (e.g., filter).

(t) Continuous temperature and humidity of the ambient air in which the PM sample media are stabilized. Determine minimum values, maximum values, average values, and percent of time outside of the tolerance over each test interval.

(u) For vehicles fueled by natural gas, the test fuel composition, including all carbon-containing compounds (including CO_2, but excluding CO). Record C_1 and C_2 compounds individually. You may record C_3 through C_5 hydrocarbons together, and you may record C_6 and heavier hydrocarbon compounds together.

(v) For vehicles fueled by liquefied petroleum gas, the test fuel composition, including all carbon-containing compounds (including CO_2, but excluding CO). Record C_1 through C_4 compounds individually. You may record C_5 and heavier hydrocarbons together.

(w) For the AC17 test in §1066.845, interior volume, climate control system type and characteristics, refrigerant used, compressor type, and evaporator/condenser characteristics.

(x) Additional information related to evaporative emissions. [Reserved]

(y) Additional information related to refueling emissions. [Reserved]

[[79 FR 23823, Apr. 28, 2016, as amended at 81 FR 74213, Oct. 25, 2016]

Subpart H—Cold Temperature Test Procedures

§ 1066.701 Applicability and general provisions.

(a) The procedures of this part 1066 may be used for testing at any ambient temperature. Section 1066.710 describes the provisions that apply for testing vehicles at a nominal temperature of −7 °C (20 °F); these procedures apply for motor vehicles as described in 40 CFR part 86, subpart S, and 40 CFR part 600. For other vehicles, see the standard-setting part to determine if your vehicle is required to meet emission standards outside the normal (20 to 30) °C ((68 to 86) °F) temperature range.

(b) Do not apply the humidity correction factor in §1066.615(a) for cold temperature testing.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9122, Feb. 19, 2015]

§ 1066.710 Cold temperature testing procedures for measuring NMOG, NO_X, PM, and CO emissions and determining fuel economy.

This section describes procedures for measuring emissions of nonmethane organic gas (NMOG), oxides of nitrogen (NO_X), particulate matter (PM), and carbon monoxide (CO) and determining fuel economy on a cold day using the FTP test cycle (see §1066.801). For Tier 3 and earlier motor vehicles, measurement procedures are based on nonmethane hydrocarbon (NMHC) emissions instead of NMOG emissions; NO_X and PM measurement requirements do not apply.

(a) Follow the exhaust emission measurement procedures specified in §§1066.410 through 1066.425 and §1066.815(d), subject to the following exceptions and additional provisions:

(1) Measure and control ambient conditions as specified in paragraph (b) of this section.

(2) Use the vehicle's heater and defroster as specified in paragraph (c) of this section.

(3) Precondition and stabilize the vehicle as specified in paragraphs (d) and (e) of this section. Ensure that there is no precipitation or dew on the vehicle before the emission test.

(4) For dynamometers that have independently heated bearings, start the emission test within 20 minutes after warming up the dynamometer; for other types of dynamometers, start the emission test within 10 minutes after warming up the dynamometer.

(5) Adjust the dynamometer to simulate vehicle operation on the road at −7 °C as described in § 1066.305(b).

(6) Analyze samples for NMOG, NO_X, PM, CO, and CO_2.

(b) Maintain ambient conditions as follows instead of following the specifications in subpart E of this part:

(1) *Ambient temperature for emission tests*. Measure and record ambient temperature in the test cell at least once every 60 seconds during the sampling period. The temperature must be (−7.0 ±1.7) °C at the start of the test and average temperature must be (−7.0 ±2.8) °C during the test. Instantaneous temperature values may be above −4.0 °C or below −9.0 °C, but not for more than 3 minutes at a time during the test. At no time may the ambient temperatures be below −12.0 °C or above −1.0 °C.

(2) *Ambient temperature for preconditioning*. Instantaneous ambient temperature values may be above −4.0 °C or below −9.0 °C but not for more than 3 minutes at a time during the preconditioning period. At no time may ambient temperatures be below −12.0 °C or above −1.0 °C. The average ambient temperature during preconditioning must be (−7.0 ±2.8) °C. You may precondition vehicles at temperatures above −7.0 °C or with a temperature tolerance greater than that described in this section (or both) if you determine that this will not cause NMOG, NO_X, PM, CO, or CO_2 emissions to decrease; if you modify the temperature specifications for vehicle preconditioning, adjust the procedures described in this section appropriately for your testing.

(3) *Ambient humidity*. Maintain humidity low enough to prevent condensation on the dynamometer rolls during testing.

(c) During the test, operate the vehicle's interior climate control system with the heat on and air conditioning off. You may not use any supplemental auxiliary heat during this testing. You may set the heater to any temperature and fan setting during vehicle preconditioning.

(1) *Manual and automatic temperature control*. Unless you rely on full automatic control as specified in paragraph (c)(2) of this section, take the following steps to control heater settings:

(i) Set the climate control system as follows before the first acceleration (t = 20 s), or before starting the vehicle if the climate control system allows it:

(A) *Temperature*. Set controls to maximum heat. For automatic temperature control systems that allow the operator to select a specific temperature, set the heater control to 72 °F or higher.

(B) *Fan speed*. Set the fan speed to full off or the lowest available speed if a full off position is not available.

(C) *Airflow direction*. Direct airflow to the front window (window defrost mode).

(D) *Air source*. If independently controllable, set the system to draw in outside air.

(ii) At the second idle of the test cycle, which occurs 125 seconds after the start of the test, set the fan speed to maximum. Complete by 130 seconds after the start of the test. Leave temperature and air source settings unchanged.

(iii) At the sixth idle of the test interval, which occurs at the deceleration to zero miles per hour 505 seconds after the start of the test, set the fan speed to the lowest setting that maintains air flow. Complete these changes by 510 seconds after the start of the test. You may use different vent and fan speed settings for the remainder of the test. Leave the temperature and air source settings unchanged.

(2) *Full automatic control*. Vehicles with full automatic control systems may instead operate as described in this paragraph (c)(2). Set the temperature to 72 °F in full automatic control for the whole test, allowing the vehicle to adjust the air temperature and direction of the airflow.

(3) *Multiple-zone systems*. For vehicles that have separate driver and passenger controls or separate front and rear controls, you must set all temperature and fan controls as described

in paragraphs (c)(1) and (2) of this section, except that rear controls need not be set to defrost the front window.

(4) *Alternative test procedures.* We may approve the use of other settings under 40 CFR 86.1840 if a vehicle's climate control system is not compatible with the provisions of this section.

(d) Take the following steps to prepare and precondition vehicles for testing under this section:

(1) Prepare the vehicle as described in § 1066.810(a).

(2) Fill the fuel tank to approximately 40% of the manufacturer's nominal fuel tank capacity. Use the appropriate gasoline test fuel for low-temperature testing as specified 40 CFR 1065.710 or use ultra low-sulfur diesel fuel as specified in 40 CFR 1065.703. However, you may ask us to approve an alternative formulation of diesel fuel under 40 CFR 1065.10(c)(1) if that better represents in-use diesel fuel in winter conditions. The temperature of the dispensed test fuel must be at or below 15.5 °C. If the leftover fuel in the fuel tank before the refueling event does not meet these specifications, drain the fuel tank before refueling. You may operate the vehicle prior to the preconditioning drive to eliminate fuel effects on adaptive memory systems.

(3) You may start the preconditioning drive once the fuel in the fuel tank reaches (−12.6 to −1.4) °C. Precondition the vehicle as follows:

(i) Push or drive the vehicle onto the dynamometer.

(ii) Operate the vehicle over one UDDS. You may perform additional vehicle preconditioning with repeated driving over the UDDS, subject to our advance approval.

(iii) Turn off the test vehicle and any cooling fans within 5 minutes after completing the preconditioning drive. Ambient temperature must be between (−12.0 and −1.0) °C in the 5 minutes following the preconditioning drive.

(iv) Do not manually purge or load the evaporative canister.

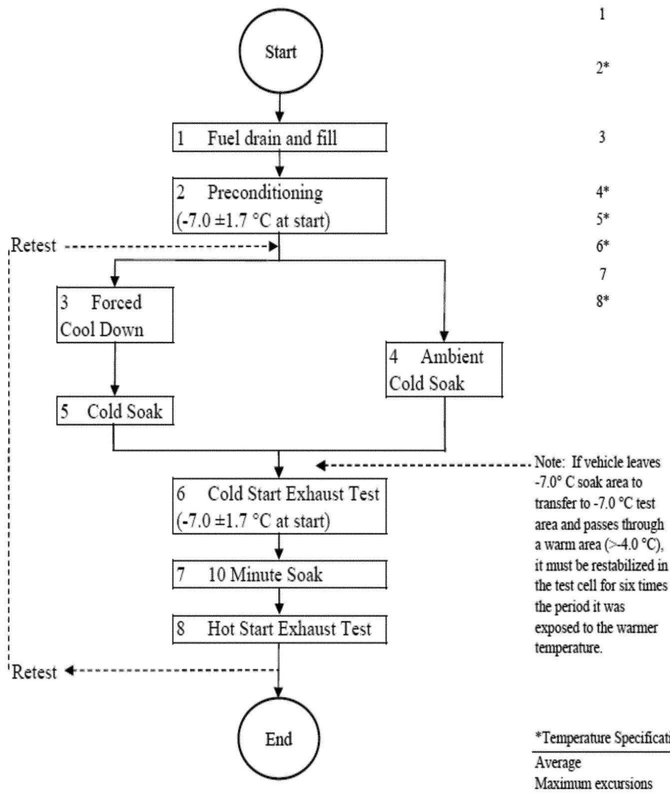
(e) Soak the vehicle for (12 to 36) hours to stabilize it at test temperatures before starting the emission test as described in this paragraph (e). If you move a stabilized vehicle through a warm area when transporting it to the dynamometer for testing, you must restabilize the vehicle by holding it at an ambient temperature within the range specified in paragraph (b)(1) of this section for at least six times as long as the vehicle was exposed to warmer temperatures. Use one of the following methods to reach a stabilized condition:

(1) *Cold storage.* Measure and record ambient temperature in the test cell at least once every 60 seconds during the ambient cold soak period. These ambient temperatures may be above −4.0 °C or below −9.0 °C, but not for more than 3 minutes at a time. Use measured values to calculate an hourly average temperature. Each hourly average temperature must be (−7.0 °C ±2.8) °C.

(2) *Forced-cooling or warming.* Position fans to blow temperature-controlled air onto the vehicle to stabilize the vehicle at the specified temperatures for emission testing. Position fans to target the vehicle's drive train, engine block, and radiator rather than the oil pan. You may not place fans under the vehicle. You may consider the vehicle to be stabilized at the test temperature when the bulk oil temperature reaches (−8.7 to −5.3) °C; measure oil temperature at one or more points away from the side or bottom surfaces of the oil pan. Each oil temperature measurement must be within the specified range before stabilization is complete. Once the vehicle reaches this stabilized condition, cold soak the vehicle within the stabilized temperature range for at least one hour before starting the emission test. During this time, keep the ambient temperature within the range specified in paragraph (b)(1) of this section.

(f) The following figure illustrates the cold temperature testing sequence for measuring CO and NMHC emissions and determining fuel economy:

FIGURE 1 TO PARAGRAPH (F) § 1066.710—COLD TEMPERATURE TESTING SEQUENCE FOR MEASURING CO AND NMHC EMISSIONS AND DETERMINING FUEL ECONOMY



Step	Note
1	Winter grade fuel (optional use of FTP fuel by manufacturer)
2*	Full UDDS (optional use of higher temperautre by manufacturer)
3	No time specifications Uniform vehicle cooling Oil temperature at -7.0 ±1.7 °C
4*	12 to 36 hours
5*	1 hour minimum
6*	Full UDDS
7	On dynamometer
8*	Partial UDDS (first 505 s)

*Temperature Specifications	
Average	-7.0 ±2.8 °C
Maximum excursions	-12.0 °C minimum, -1.0 °C maximum
Three-minute excursions	-9.0 °C minimum, -4.0 °C maximum

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9122, Feb. 19, 2015; 81 FR 74213, Oct. 25, 2016; 86 FR 34583, June 29, 2021; 88 FR 4708, Jan. 24, 2023; 89 FR 28212, Apr. 18, 2024]

Subpart I—Exhaust Emission Test Procedures for Motor Vehicles

§ 1066.801 Applicability and general provisions.

This subpart I specifies how to apply the test procedures of this part for light-duty vehicles, light-duty trucks, and heavy-duty vehicles at or below 14,000 pounds GVWR that are subject to chassis testing for exhaust emissions under 40 CFR part 86, subpart S. For these vehicles, references in this part 1066 to the standard-setting part include subpart H of this part and this subpart I.

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

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

(c) This subpart covers the following test procedures:

(1) The Federal Test Procedure (FTP), which includes the general driving cycle. This procedure is also used for measuring evaporative emissions. This may be called the conventional test since it was adopted with the earliest emission standards.

(i) The FTP consists of one Urban Dynamometer Driving Schedule (UDDS) as specified in paragraph (a) of appendix I to 40 CFR part 86, followed by a 10-minute soak with the engine off and repeat driving through the first 505 seconds of the UDDS. Note that the UDDS represents about 7.5 miles of driving in an urban area. Engine start-up (with all accessories turned off), operation over the initial UDDS, and engine shutdown make a complete cold-start test. The hot-start test consists of the first 505 seconds of the UDDS following the 10-minute soak and a hot-running portion of the UDDS after the first 505 seconds. The first 505 seconds of the UDDS is considered the transient portion; the remainder of the UDDS is considered the stabilized (or hot-stabilized) portion. The hot-stabilized portion for the hot-start test is generally measured during the cold-start test; however, in certain cases, the hot-start test may involve a second full UDDS following the 10-minute soak, rather than repeating only the first 505 seconds. See §§ 1066.815 and 1066.820.

(ii) Evaporative emission testing includes a preconditioning drive with the UDDS and a full FTP cycle, including exhaust measurement, followed by evaporative emission measurements. In the three-day diurnal test sequence, the exhaust test is followed by a running loss test consisting of a UDDS, then two New York City Cycles as specified in paragraph (e) of appendix I to 40 CFR part 86, followed by another UDDS; see 40 CFR 86.134. Note that the New York City Cycle represents about 1.18 miles of driving in a city center. The running loss test is followed by a high-temperature hot soak test as described in 40 CFR 86.138 and a three-day diurnal emission test as described in 40 CFR 86.133. In the two-day diurnal test sequence, the exhaust test is followed by a low-temperature hot soak test as described in 40 CFR 86.138–96(k) and a two-day diurnal emission test as described in 40 CFR 86.133–96(p).

(iii) Refueling emission tests for vehicles that rely on integrated control of diurnal and refueling emissions includes vehicle operation over the full FTP test cycle corresponding to the three-day diurnal test sequence to precondition and purge the evaporative canister. For non-integrated systems, there is a preconditioning drive over the UDDS and a refueling event, followed by repeated UDDS driving to purge the evaporative canister. The refueling emission test procedures are described in 40 CFR 86.150 through 86.157.

(2) The US06 driving cycle is specified in paragraph (g) of appendix I to 40 CFR part 86. Note that the US06 driving cycle represents about 8.0 miles of relatively aggressive driving.

(3) The SC03 driving cycle is specified in paragraph (h) of appendix I to 40 CFR part 86. Note that the SC03 driving schedule represents about 3.6 miles of urban driving with the air conditioner operating.

(4) The hot portion of the LA–92 driving cycle is specified in paragraph (c) of appendix I to 40 CFR part 86. Note that the hot portion of the LA–92 driving cycle represents about 9.8 miles of relatively aggressive driving for commercial trucks. This driving cycle applies for heavy-duty vehicles above 10,000 pounds GVWR and at or below 14,000 pounds GVWR only for vehicles subject to Tier 3 standards.

(5) The Highway Fuel Economy Test (HFET) is specified in appendix I to 40 CFR part 600. Note that the HFET represents about 10.2 miles of rural and freeway driving with an average speed of 48.6 mi/hr and a maximum speed of 60.0 mi/hr. See § 1066.840.

(6) Cold temperature standards apply for $NMOG+NO_X$ (or NMHC), PM, and CO emissions when vehicles operate over the FTP at a nominal temperature of -7 °C. See subpart H of this part.

(7) Emission measurement to determine air conditioning credits for greenhouse gas standards. In this optional procedure, manufacturers operate vehicles over repeat runs of the AC17 test sequence to allow for calculating credits as part of demonstrating compliance with CO_2 emission standards. The AC17 test sequence consists of a UDDS preconditioning drive, followed by emission measurements over the SC03 and HFET driving cycles. See § 1066.845.

(8) The mid-temperature intermediate soak FTP is specified as the procedure for Partial Soak Emission Testing in Section E4.4 of California

ARB's PHEV Test Procedures for plug-in hybrid electric vehicles, in Part II Section I.7 of California ARB's LMDV Test Procedures for other hybrid electric vehicles, and in Part II, Section B.9.1 and B.9.3 of California ARB's LMDV Test Procedures for other vehicles (both incorporated by reference, see §1066.1010).

(9) The early driveaway FTP is specified as the procedure for Quick Drive-Away Emission Testing in Section E4.5 of California ARB's PHEV Test Procedures for plug-in hybrid electric vehicles, in Part II Section I.8 of California ARB's LMDV Test Procedures for other hybrid electric vehicles, and in Part II, Section B.9.2 and B.9.4 of California ARB's LMDV Test Procedures for other vehicles (both incorporated by reference, see §1066.1010). Additionally, vehicle speed may not exceed 0.0 mi/hr until 7.0 seconds into the driving schedule and vehicle speed may not exceed 2.0 mi/hr from 7.1 through 7.9 seconds.

(10) The high-load PHEV engine starts US06 is specified in Section E7.2 of California ARB's PHEV Test Procedures using the cold-start US06 Charge-Depleting Emission Test (incorporated by reference, see §1066.1010).

(d) The following provisions apply for all testing:

(1) Ambient temperatures encountered by the test vehicle must be (20 to 30) °C, unless otherwise specified. Where ambient temperature specifications apply before or between test measurements, the vehicle may be exposed to temperatures outside of the specified range for up to 10 minutes to account for vehicle transport or other actions to prepare for testing. The temperatures monitored during testing must be representative of those experienced by the test vehicle. For example, do not measure ambient temperatures near a heat source.

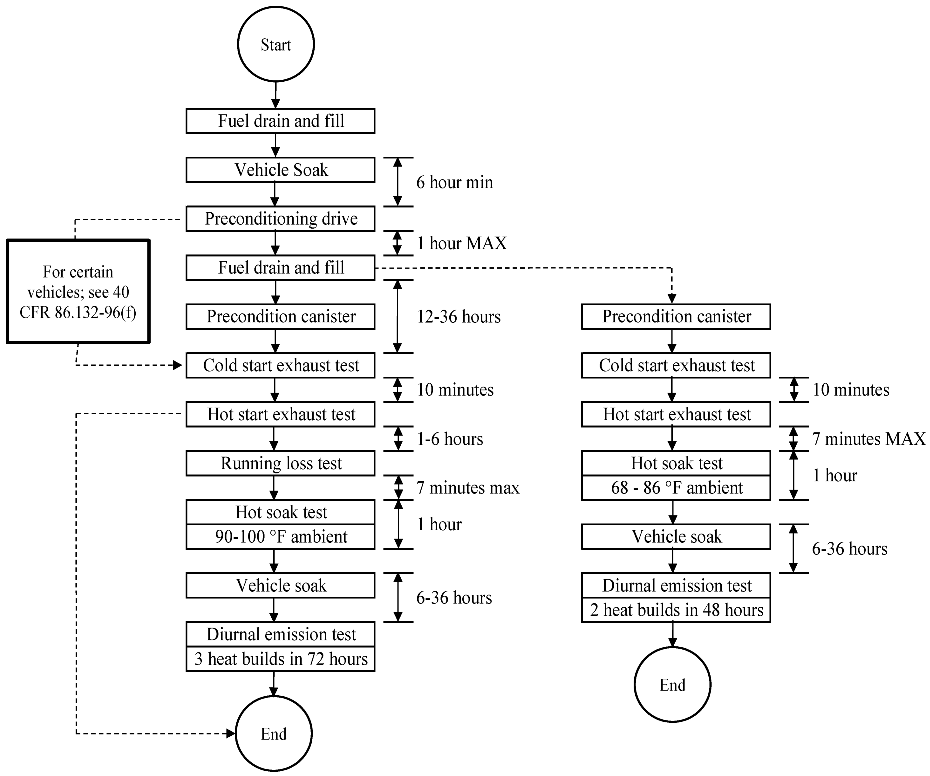
(2) Do not operate or store the vehicle at an incline if good engineering judgment indicates that it would affect emissions.

(3) If a test is void after collecting emission data from previous test segments, the test may be repeated to collect only those data points needed to complete emission measurements. You may combine emission measurements from different test runs to demonstrate compliance with emission standards.

(4) Prepare vehicles for testing as described in §1066.810.

(e) The following figure illustrates the FTP test sequence for measuring exhaust and evaporative emissions:

FIGURE 1 TO PARAGRAPH (E)—FTP TEST SEQUENCE



[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9123, Feb. 19, 2015; 81 FR 74213, Oct. 25, 2016; 86 FR 34583, June 29, 2021; 89 FR 28213, Apr. 18, 2024]

§ 1066.805 Road-load power, test weight, and inertia weight class determination.

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

TABLE 1 OF § 1066.805—EQUIVALENT TEST WEIGHTS (POUNDS)

Test weight	Equivalent test	Inertia weight
Up to 1062	1000	1000
1063 to 1187	1125	1000
1188 to 1312	1250	1250
1313 to 1437	1375	1250
1438 to 1562	1500	1500
1563 to 1687	1625	1500
1688 to 1812	1750	1750
1813 to 1937	1875	1750
1938 to 2062	2000	2000
2063 to 2187	2125	2000
2188 to 2312	2250	2250
2313 to 2437	2375	2250
2438 to 2562	2500	2500
2563 to 2687	2625	2500
2688 to 2812	2750	2750
2813 to 2937	2875	2750
2938 to 3062	3000	3000
3063 to 3187	3125	3000
3188 to 3312	3250	3000
3313 to 3437	3375	3500
3438 to 3562	3500	3500
3563 to 3687	3625	3500
3688 to 3812	3750	3500
3813 to 3937	3875	4000
3938 to 4125	4000	4000

TABLE 1 OF § 1066.805—EQUIVALENT TEST WEIGHTS (POUNDS)—Continued

Test weight	Equivalent test	Inertia weight
4126 to 4375	4250	4000
4376 to 4625	4500	4500
4626 to 4875	4750	4500
4876 to 5125	5000	5000
5126 to 5375	5250	5000
5376 to 5750	5500	5500
5751 to 6250	6000	6000
6251 to 6750	6500	6500
6751 to 7250	7000	7000
7251 to 7750	7500	7500
7751 to 8250	8000	8000
8251 to 8750	8500	8500
8751 to 9250	9000	9000
9251 to 9750	9500	9500
9751 to 10250	10000	10000
10251 to 10750	10500	10500
10751 to 11250	11000	11000
11251 to 11750	11500	11500
11751 to 12250	12000	12000
12251 to 12750	12500	12500
12751 to 13250	13000	13000
13251 to 13750	13500	13500
13751 to 14000	14000	14000

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

(c) For FTP, US06, SC03, New York City Cycle, HFET, and LA–92 testing, determine road-load forces for each test vehicle at speeds between 9.3 and 71.5 miles per hour. The road-load force must represent vehicle operation on a smooth, level road with no wind or calm winds, no precipitation, an ambient temperature of approximately 20 °C, and atmospheric pressure of 98.21 kPa. You may extrapolate road-load force for speeds below 9.3 mi/hr.

[79 FR 23823, Apr. 28, 2016, as amended at 81 FR 74213, Oct. 25, 2016; 89 FR 18214, Apr. 18, 2024]

§ 1066.810 Vehicle preparation.

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

(b) For preconditioning that involves loading an evaporative emission canister with butane, provide valving or other means to allow for purging and loading the canister.

(c) For vehicles to be tested for running loss emissions (40 CFR 86.134), prepare the fuel tank for measuring temperature and pressure as specified in 40 CFR 86.107–98(e) and (f) and 40 CFR 86.134. Vapor temperature measurement is optional during the running loss test.

(d) For vehicles to be tested for running loss emissions, prepare the exhaust system by sealing or plugging all detectable sources of exhaust gas leaks. Inspect or test the exhaust system to ensure that there are no leaks that would cause exhaust hydrocarbon emissions to be detected as running losses.

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

(1) You must notify us in advance if you plan to perform such preconditioning. This notice must include a detailed description of the intended procedures and any measurements or thresholds for determining when stabilization is complete. You need not repeat this notification for additional vehicle testing in the same or later model years as long as your preconditioning practice conforms to these procedures.

(2) You may precondition a vehicle as described in paragraph (e)(1) of this section only within 12 months after the vehicle's original date of manufacture, except that you may ask us to approve further preconditioning steps for any testing to address identifiable sources of nonfuel emissions beyond what would generally occur with an appropriately aged in-use vehicle. For example, you may clean up fluid leaks and you may perform further off-vehicle preconditioning for tires or other replacement parts that are less than 12 months old. You may also replace the spare tire with an aged spare tire, and you may replace the windshield washer fluid with water.

§ 1066.815 Exhaust emission test procedures for FTP testing.

(a) *General.* The FTP exhaust emission test sequence consists of a cold-start test and a hot-start test as described in § 1066.801.

(b) *PM sampling options.* Collect PM using any of the procedures specified in paragraphs (b)(1) through (5) of this section and use the corresponding equation in §1066.820 to calculate FTP composite emissions. Testing must meet the requirements related to filter face velocity as described in §1066.110(b)(2)(iii)(C), except as specified in paragraphs (b)(4) and (5) of this section. For procedures involving flow weighting, set the filter face velocity to a weighting target of 1.0 to meet the requirements of §1066.110(b)(2)(iii)(C). Allow filter face velocity to decrease as a percentage of the weighting factor if the weighting factor is less than 1.0 and do not change the nominal CVS flowrates or secondary dilution ratios between FTP or UDDS test intervals. Use the appropriate equations in §1066.610 to show that you meet the dilution factor requirements of §1066.110(b)(2)(iii)(B). If you collect PM using the procedures specified in paragraph (b)(4) or (5) of this section, the residence time requirements in 40 CFR 1065.140(e)(3) apply, except that you may exceed an overall residence time of 5.5 s for sample flow rates below the highest expected sample flow rate.

(1) You may collect a separate PM sample for transient and stabilized portions of the cold-start UDDS and the hot-start UDDS. This may either be done by sampling with three bags or four bags. You may omit the stabilized portion of the hot-start test (bag 4) and use the stabilized portion of the cold-start test (bag 2) in its place.

(2) You may collect PM on one filter over the cold-start UDDS and on a separate filter over the hot-start UDDS.

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

(4) You may collect PM on a single filter over the cold-start UDDS and the first 505 seconds of the hot-start UDDS using one of the following methods:

(i) Adjust your sampling system flow rate over the filter to weight the filter face velocity over the three intervals of the FTP based on weighting targets of 0.43 for bag 1, 1.0 for bag 2, and 0.57 for bag 3.

(ii) Maintain a constant sampling system flow rate over the filter for all three intervals of the FTP by increasing overall dilution ratios for bag 1 and bag 3. To do this, reduce the sample flow rate from the exhaust (or diluted exhaust) such that the value is reduced to 43% and 57%, respectively, of the bag 2 values. For constant-volume samplers, this requires that you decrease the dilute exhaust sampling rate from the CVS and compensate for that by increasing the amount of secondary dilution air.

(5) You may collect PM on a single filter over the cold-start UDDS and the full hot-start UDDS using one of the following methods:

(i) Adjust your sampling system flow rate over the filter to weight the filter face velocity based on weighting targets of 0.75 for the cold-start UDDS and 1.0 for the hot-start UDDS.

(ii) Maintain a constant sampling system flow rate over the filter for both the cold-start and hot-start UDDS by increasing the overall dilution ratio for the cold-start UDDS. To do this, reduce the sample flow rate from the exhaust (or diluted exhaust) such that the value is reduced to 75% of the hot-start UDDS value. For constant-volume samplers, this requires that you decrease the dilute exhaust sampling rate from the CVS and compensate for that by increasing the amount of secondary dilution air.

(c) *Gaseous sampling options.* Collect gaseous samples using any of the following procedures:

(1) You may collect a single sample for a full UDDS (cold-start or hot-start).

(2) You may sample emissions separately for transient and stabilized portions of any UDDS.

(3) You may omit the stabilized portion of the hot-start test (bag 4) and use the stabilized portion of the cold-start test (bag 2) in its place.

(d) *Test sequence.* Follow the exhaust emission measurement procedures specified in §§1066.410 through 1066.425, subject to the following exceptions and additional provisions:

(1) Take the following steps for the cold-start test:

(i) Precondition the vehicle as described in §1066.816. Initiate the cold-start test following the 12 to 36 hour soak period.

(ii) Simultaneously start any electronic integrating devices, continuous data recording, and batch sampling before attempting to start the engine. Initiate the sequence of points in the test cycle when the engine starts. Place the vehicle in gear 15 seconds after engine starting, which is 5 seconds before the first acceleration.

(iii) At the end of the deceleration scheduled to occur 505 seconds into the cold-start UDDS, simultaneously switch all the sample flows from the cold-start transient interval to the stabilized interval, stopping all cold-start transient interval sampling and recording, including background sampling. Reset integrating devices for the stabilized interval and indicate the end of the cold-start interval in the recorded data. Operate the vehicle over the remainder of the UDDS. Turn the engine off 2 seconds after the end of the last deceleration in the stabilized interval (1,369 seconds after the start of the driving schedule).

(iv) Five seconds after the engine stops running, stop all stabilized interval sampling and recording, including background sampling. Stop any integrating devices for the stabilized interval and indicate the end of the stabilized interval in the recorded data. Note that the 5 second delay is intended to account for sampling system transport.

(2) Take the following steps for the hot-start test:

(i) Initiate the hot-start test (9 to 11) minutes after the end of the sample period for the cold-start UDDS.

(ii) Repeat the steps in paragraph (d)(1)(ii) of this section. Operate the vehicle over the first 505 seconds of the UDDS. For tests that do not include bag 4 operation, turn off the engine and simultaneously stop all hot-start sampling and recording, including background sampling, and any integrating devices at the end of the deceleration scheduled to occur 505 seconds into the hot-start UDDS.

(iii) To include bag 4 measurement, operate the vehicles over the remainder of the UDDS and conclude the testing as described in paragraphs (d)(1)(iii) and (iv) of this section.

(3) This completes the procedure for measuring FTP exhaust emissions. See §1066.801 and subpart J of this part for continuing the test sequence to measure evaporative or refueling emissions.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9124, Feb. 19, 2015; 81 FR 74213, Oct. 25, 2016; 88 FR 4709, Jan. 24, 2023]

§ 1066.816 Vehicle preconditioning for FTP testing.

Precondition the test vehicle before the FTP exhaust measurement as described in 40 CFR 86.132.

§ 1066.820 Composite calculations for FTP exhaust emissions.

(a) Determine the mass of exhaust emissions of each pollutant for each FTP test interval as described in §1066.605.

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

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

Eq. 1066.820-1

Where:

m_c = the combined mass emissions determined from the cold-start UDDS test interval (generally known as bag 1 and bag 2), in grams.

D_{ct} = the measured driving distance from the transient portion of the cold-start test (bag 1), in miles.

D_{cs} = the measured driving distance from the stabilized portion of the cold-start test (bag 2), in miles.

m_h = the combined mass emissions determined from the hot-start UDDS test interval in grams. This is the hot-stabilized portion from either the first or second UDDS (bag 2, unless you measure bag 4), in addition to the hot transient portion (bag 3).

D_{ht} = the measured driving distance from the transient portion of the hot-start test (bag 3), in miles.

D_{hs} = the measured driving distance from the stabilized portion of the hot-start test (bag 4), in miles. Set D_{hs} = D_{cs} for testing where the hot-stabilized portion of the UDDS is not run.

(c) Calculate the final composite PM test results as a mass-weighted value, $e_{PM-FTPcomp}$, in grams per mile as follows:

(1) Use the following equation for PM measured as described in § 1066.815(b)(1), (2), or (3):

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

Eq. 1066.820-2

Where:

$m_{PM-cUDDS}$ = the combined PM mass emissions determined from the cold-start UDDS test interval (bag 1 and bag 2), in grams, as calculated using Eq. 1066.605–3.

$m_{PM-hUDDS}$ = the combined PM mass emissions determined from the hot-start UDDS test interval (bag 3 and bag 4), in grams, as calculated using Eq. 1066.605–3. This is the hot-stabilized portion from either the first or second UDDS (bag 2, unless you measure bag 4), in addition to the hot transient portion (bag 3).

(2) Use the following equation for PM measured as described in § 1066.815(b)(4):

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

Eq. 1066.820-3

Where:

m_{PM} = the combined PM mass emissions determined from the cold-start UDDS test interval and the first 505 seconds of the hot-start UDDS test interval (bag 1, bag 2, and bag 3), in grams, as calculated using Eqs. 1066.605–4 and 1066.605–5.

(3) Use the following equation for PM measured as described in § 1066.815(b)(5):

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

Eq. 1066.820-4

Where:

m_{PM} = the combined PM mass emissions determined from the cold-start UDDS test interval and the hot-start UDDS test interval (bag 1, bag 2, bag 3, and bag 4), in grams, as calculated using Eqs. 1066.605–6 and 1066.605–7.

[79 FR 23823, Apr. 28, 2016, as amended at 81 FR 74214, Oct. 25, 2016]

§ 1066.830 Supplemental Federal Test Procedures; overview.

Sections 1066.831 and 1066.835 describe the detailed procedures for the Supplemental Federal Test Procedure (SFTP). This testing applies for Tier 3 vehicles subject to the SFTP standards in 40 CFR 86.1811–17 or 86.1816–18. The SFTP test procedure consists of FTP testing and two additional test elements—a sequence of vehicle operation with more aggressive driving and a sequence of vehicle operation that accounts for the impact of the vehicle's air conditioner. Tier 4 vehicles subject to 40 CFR 86.1811–27 must meet standards for each individual driving cycle.

(a) The SFTP standard applies as a composite representing the three test elements. The emission results from the aggressive driving test element (§ 1066.831), the air conditioning test element (§ 1066.835), and the FTP test element (§ 1066.820) are analyzed according to the calculation methodology and compared to the applicable SFTP emission standards as described in 40 CFR part 86, subpart S.

(b) The test elements of the SFTP may be run in any sequence that includes the specified preconditioning steps.

[89 FR 28215, Apr. 18, 2024]

§ 1066.831 Exhaust emission test procedures for aggressive driving.

(a) This section describes how to test using the US06 or LA–92 driving schedule. The US06 driving schedule can be divided into two test intervals—the US06 City cycle comprises the combined portions of the cycle from 1 to 130 seconds and from 495 to 596 seconds, and the US06 Highway cycle comprises the portion of the cycle between 130 and 495 seconds. See § 1066.801 for further information on the driving schedules.

(b) Take the following steps to precondition vehicles for testing under this section:

(1) Drain and refill the vehicle's fuel tank(s) in any of the following cases:

(i) For aggressive-driving tests that do not follow FTP or HFET testing.

(ii) For a test element that starts more than 72 hours after the most recent FTP or HFET measurement (with or without evaporative emission measurements).

(iii) For testing in which the test vehicle has not remained in an area where ambient temperatures were within the range specified for testing since the previous FTP or HFET.

(2) Keep ambient temperatures within the ranges specified for test measurements throughout the preconditioning sequence.

(3) Warm up the vehicle to a stabilized condition as follows:

(i) Push or drive the vehicle onto the dynamometer.

(ii) Operate the vehicle one time over one of the driving schedules specified in this paragraph (b)(3)(ii). You may ask us to use a particular preconditioning driving schedule if that is related to fuel effects on adaptive memory systems. For our testing, we will generally operate the vehicle over the same preconditioning cycle that will be used for testing in this section. You may exercise your sampling equipment, but you may not determine emissions results during preconditioning. Choose from the following driving schedules:

(A) The first 505 seconds of the UDDS (bag 1).

(B) The last 867 seconds of the UDDS (bag 2).

(C) The HFET driving schedule.

(D) US06 driving schedule or, for heavy-duty vehicles at or below 10,000 pounds GVWR with a power-to-weight ratio at or below 0.024 hp/lbm, just the highway portion of the US06 driving schedule.

(E) The SC03 driving schedule.

(F) The LA–92 driving schedule.

(G) The Hot LA–92 driving schedule.

(4) Allow the vehicle to idle for (1 to 2) minutes. This leads directly into the test measurements described in paragraph (c) of this section.

(c) For testing involving the full US06 driving schedule, you may collect emissions from separate city and highway test intervals (see 40 CFR part 600), or you may collect emissions over the full US06 driving schedule as a single test interval. Take the following steps to measure emissions over separate city and highway test intervals:

(1) At 130 seconds, simultaneously stop all US06 City, and start all US06 Highway sampling, recording, and integrating (including background sampling). At 136 seconds (before the acceleration), record the measured dynamometer roll revolutions.

(2) At 495 seconds, simultaneously stop all US06 Highway, and start all US06 City sampling, recording, and integrating (including background sampling). At 500 seconds (before the acceleration), record the measured dynamometer roll revolutions.

(3) Except as specified in paragraph (c)(4) of this section, treat the emissions from the first and second portions of the US06 City test interval as a single sample.

(4) If you collect gaseous emissions over separate city and highway test intervals, you may still collect PM over the full US06 driving schedule as a single test interval. If you do this, calculate a composite dilution factor based on city and highway emissions using Eq. 1066.610–4 to show that you meet the dilution factor requirements of § 1066.110(b)(2)(iii)(B).

(d) For diesel-fueled vehicles, measure THC emissions on a continuous basis. For separate measurement of the city and highway test intervals as described in paragraph (c) of this section, perform separate calculations for each portion of the test cycle.

(e) Follow the exhaust emission measurement procedures specified in §§ 1066.410 through 1066.425, subject to the following exceptions and additional provisions:

(1) Following the preconditioning specified in paragraph (b) of this section, place the vehicle in gear and simultaneously start sampling and recording. Begin the first acceleration 5 seconds after placing the vehicle in gear.

(2) Operate the vehicle over the full US06 driving schedule, with the following exceptions that apply only for Tier 3 vehicles:

(i) For heavy-duty vehicles above 10,000 pounds GVWR, operate the vehicle over the Hot LA–92 driving schedule.

(ii) Heavy-duty vehicles at or below 10,000 pounds GVWR with a power-to-weight ratio at or below 0.024 hp/pound may be certified using only the highway portion of the US06 driving schedule as described in 40 CFR 86.1816.

(3) Turn the engine off 2 seconds after the end of the last deceleration. Five seconds after the engine stops running, stop all sampling and recording, including background sampling. Stop any integrating devices and indicate the end of the test cycle in the recorded data. Note that the 5 second delay is intended to account for sampling system transport.

(4) Correct calculated NO_X emissions as described in § 1066.615(a)(1).

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9124, Feb. 19, 2015; 88 FR 4709, Jan. 24, 2023; 89 FR 28215, Apr. 18, 2024]

§ 1066.835 Exhaust emission test procedure for SC03 emissions.

This section describes how to test using the SC03 driving schedule (see § 1066.801). This procedure is designed to determine gaseous exhaust emissions while simulating an urban trip on a hot summer day. The provisions of 40 CFR part 86 and 40 CFR part 600 waive SC03 testing for some vehicles; in those cases, calculate SFTP composite emissions by adjusting the weighting calculation as specified in 40 CFR part 86, subpart S.

(a) Drain and refill the vehicle's fuel tank(s) if testing starts more than 72 hours after the most recent FTP or HFET measurement (with or without evaporative emission measurements).

(b) Keep the vehicle in an environment meeting the conditions described in paragraph (f) of this section throughout the preconditioning sequence.

(c) Warm up the vehicle to a stabilized condition as follows:

(1) Push or drive the test vehicle onto the dynamometer.

(2) Close the vehicle's windows before testing.

(3) The test cell and equipment must meet the specifications in paragraph (e) of this section. Measure and control ambient conditions as specified in paragraph (f) of this section.

(4) Set the vehicle's air conditioning controls by selecting A/C mode and "maximum", setting airflow to "recirculate" (if so equipped), selecting the highest fan setting, and turning the A/C temperature to full cold (or 72 °F for automatic systems). Turn the control to the "on" position before testing so the air conditioning system is active whenever the engine is running.

(5) Perform a preconditioning drive by operating the test vehicle one time over the first 505 seconds of the UDDS (bag 1), the last 867 seconds of the UDDS (bag 2), or the SC03 driving schedule. If the air conditioning test sequence starts more than 2 hours after a different exhaust emission test, you may instead operate the vehicle one time over the full UDDS.

(6) Following the preconditioning drive, turn off the test vehicle and the vehicle cooling fan(s) and allow the vehicle to soak for (9 to 11) minutes.

(d) Follow the exhaust emission measurement procedures specified in §§1066.410 through 1066.425, subject to the following exceptions and additional provisions:

(1) Place the vehicle in gear 15 seconds after engine starting, which is 3 seconds before the first acceleration. Follow the SC03 driving schedule.

(2) Turn the engine off 2 seconds after the end of the last deceleration. Five seconds after the engine stops running, stop all sampling and recording, including background sampling. Stop any integrating devices any indicate the end of the test cycle in the recorded data. Note that the 5 second delay is intended to account for sampling system transport.

(3) Correct calculated NO_X emissions as described in §1066.615(a)(2).

(e) The following requirements apply for the test cell and cooling fan configuration:

(1) *Minimum test cell size.* The test cell must be at least 20 feet wide, 40 feet long, and 10 feet high, unless we approve the use of a smaller test cell. We will approve this only if you demonstrate that the smaller test cell is capable of meeting all the requirements of this section.

(2) *Vehicle frontal air flow.* Verify that the fan configuration meets the requirements of §1066.105(c)(5).

(f) Maintain ambient conditions as follows:

(1) *Ambient temperature and humidity.* Measure and record ambient temperature and humidity in the test cell at least once every 30 seconds during the sampling period. Alternatively, if you collect data of at least once every 12 seconds, you may use a moving average of up to 30 second intervals to measure and record ambient temperature and humidity. Control ambient temperature throughout the test sequence to (35.0 ± 3.0) °C. Control ambient temperature during emission sampling to (33.6 to 36.4) °C on average. Control ambient humidity during emission sampling as described in §1066.420(d).

(2) *Conditions before testing.* Use good engineering judgment to demonstrate that you meet the specified temperature and humidity tolerances in paragraph (f)(1) of this section during the preconditioning cycle and during the vehicle soak period in paragraph (c)(6) of this section.

(3) *Solar heat load.* Simulate solar heating as follows:

(i) You may use a metal halide lamp, a sodium lamp, or a quartz halogen lamp with dichroic mirrors as a radiant energy emitter. We may also approve the use of a different type of radiant energy emitter if you demonstrate that it meets the requirements of this section.

(ii) We recommend achieving radiant heating with spectral distribution characteristics as described in the following table:

TABLE 1 OF §1066.835—RECOMMENDED SPECTRAL DISTRIBUTION

Band width (nm)	Percent of total spectrum	
	Lower limit (%)	Upper limit (%)
<320[a]		0
320–400	0	7
400–780	45	55
>780	35	53

[a] Note that you may need to filter the UV region between 280 and 320 nm.

(iii) Determine radiant energy intensity experienced by the vehicle as the average value between two measurements along the vehicle's centerline, one at the base of the windshield and the other at the bottom of the rear window (or equivalent location for vehicles without a rear window). This value must be (850 ± 45) W/m^2. Instruments for measuring radiant energy intensity must meet the following minimum specifications:

(A) Sensitivity of 9 microvolts per W/m^2.

(B) Response time of 5 seconds. For purposes of this requirement, "response time" means the time for the instrument to reach 95 percent of its equilibrium response after a step change in radiant intensity.

(C) Cosine response error of no more than ±1% for 0–70 degree zenith angles. The cosine response error is the percentage difference between the intensity measured at a given angle and a reference value, where the reference value is the intensity predicted from the zero-degree intensity and the cosine of the incident angle.

(D) When comparing measured values for radiant energy to reference values, each measured value over the full range of measurement may not deviate from the corresponding reference value by more than ±0.5% of the analyzer range's maximum value.

(iv) Check the uniformity of radiant energy intensity at least every 500 hours of emitter usage or every 6 months, whichever is sooner, and after any major modifications affecting the solar simulation. Determine uniformity by measuring radiant energy intensity using instruments that meet the specifications described in paragraph (f)(3)(iii) of this section at each point of a 0.5 m grid over the vehicle's full footprint, including the edges of the footprint, at an elevation 1 m above the floor. Measured values of radiant energy intensity must be between (722 and 978) W/m^2 at all points.

[79 FR 23823, Apr. 28, 2014, as amended at 80 FR 9124, Feb. 19, 2015; 81 FR 74214, Oct. 25, 2016; 86 FR 34584, June 29, 2021; 88 FR 4709, Jan. 24, 2023]

§ 1066.840 Highway fuel economy test procedure.

This section describes the procedure for the highway fuel economy test (HFET). This test involves emission sampling and fuel economy measurement for certain vehicles as described in 40 CFR part 86, subpart S, and in 40 CFR part 600. See § 1066.801 for further information on the driving schedules. Follow the exhaust emission measurement procedures specified in §§ 1066.410 through 1066.425, subject to the following exceptions and additional provisions:

(a) Perform the HFET immediately following the FTP when this is practical. If the HFET procedure starts more than 3 hours after an FTP (including evaporative emission measurements, if applicable), operate it over one UDDS to precondition the vehicle. We may approve additional preconditioning in unusual circumstances.

(b) Operate the vehicle over the HFET driving schedule for preconditioning. Allow the vehicle to idle for 15 seconds (with the vehicle in gear), then start a repeat run of the HFET driving schedule and simultaneously start sampling and recording.

(c) Turn the engine off at the end of the HFET driving schedule and stop all sampling and recording, including background. Stop any integrating devices and indicate the end of the test cycle in the recorded data.

§ 1066.845 AC17 air conditioning efficiency test procedure.

(a) *Overview.* This section describes a voluntary procedure for measuring the net impact of air conditioner operation on CO_2 emissions. See 40 CFR 86.1868 for provisions describing how to use these procedures to calculate credits and otherwise comply with emission standards.

(b) *Test cell.* Operate the vehicle in a test cell meeting the specifications described in § 1066.835(e). You may add airflow up to a maximum of 4 miles per hour during engine idling and when the engine is off if that is needed to meet ambient temperature or humidity requirements.

(c) *Ambient conditions.* Measure and control ambient conditions as specified in § 1066.835(f), except that you must control ambient temperature during emission sampling to (22.0 to 28.0) °C throughout the test and (23.5 to 26.5) °C on average. These tolerances apply to the combined SC03 and HFET drive cycles during emission sampling. Note that you must set the same ambient temperature target for both the air conditioning on and off portions of emission sampling. Control ambient temperature during the preconditioning cycle and 30 minute soak to (25.0 ± 5.0) °C. For these same modes with no emission sampling, target the specified ambient humidity levels, but you do not need to meet the humidity tolerances. Note that solar heating is disabled for certain test intervals as described in this section.

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

(e) *Air conditioning system settings.* For testing that requires the air conditioning to be operating, set the vehicle's air conditioning controls as follows:

(1) For automatic systems, set the temperature control to 72 °F (22 °C).

(2) For manual systems, select A/C mode, set the temperature to full cold and ''maximum'', set airflow to ''recirculate'' (if so equipped), and select the highest fan setting. During the first idle period of the SC03 driving schedule (between 186 and 204 seconds), reduce the fan speed setting to nominally 50% of maximum fan speed, set airflow to ''fresh air'' (if so equipped), and adjust the temperature setting to target a temperature of 55 °F (13 °C) at the dashboard air outlet. Maintain these settings for the remainder of the test. You may rely on prior temperature measurements to determine the temperature setting; however, if the system is unable to meet the 55 °F (13 °C) target, you may instead set airflow to ''fresh air'' and temperature to full cold. If the vehicle is equipped with technology that defaults to recirculated air at ambient temperatures above 75 °F (22 °C), that technology should remain enabled throughout the test; this may mean not setting the airflow to ''recirculate'' at the start and not setting the airflow to ''fresh air'' during the first idle period of the SC03 driving schedule. Except as specified in paragraph (e)(3) of this section, use good engineering judgment to apply the settings described in this paragraph (e)(2) equally throughout the vehicle if there are separate controls for different zones (such as rear air conditioning).

(3) If the air conditioning system is designed with parameters that switch back to a default setting at key-off, perform testing in that default condition. If the air conditioning system includes any optional equipment or user controls not addressed in this paragraph (e), the manufacturer should ask us for preliminary approval to determine the appropriate settings for testing.

(f) *Test procedure.* Follow the exhaust emission measurement procedures specified in §§ 1066.410 through 1066.425, subject to the following exceptions and additional provisions:

(1) Prepare each test vehicle for a series of tests according to 40 CFR 86.132–00(a) through (g). If the vehicle has been tested within the last 36 hours concluding with a 12 to 36 hour soak, continue to paragraph (f)(2) of this section; otherwise perform an additional UDDS preconditioning cycle that concludes with a 12 to 36 hour soak. You may use a forced cooldown system to bring critical vehicle temperatures to within soak temperature limits. Critical temperatures include transmission oil, engine oil, engine coolant, and cabin air temperatures.

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

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

(4) Turn the air conditioning control to the ''on'' position before testing so the air conditioning system is active whenever the engine is running. Place the vehicle in gear 15 seconds after engine starting, which is 3 seconds before the first acceleration. At the end of the driving schedule, simultaneously switch all the sampling, recording, and integrating from SC03 to HFET, including background sampling. Indicate the end of the test cycle in the recorded data. Record the measured dynamometer roll revolutions corresponding to the SC03 driving schedule.

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

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

(g) *Calculations.* (1) Determine the mass of CO_2 emissions for each of the two test intervals as described in §1066.605.

(2) Calculate separate composite mass-weighted emissions of CO_2, $e_{CO2\text{–}AC17compAC[status]}$, representing the average of the SC03 and HFET emissions, in grams per mile for operation with the vehicle's air conditioner and the solar heating on and off using the following equation:

$$e_{\text{CO2-AC17compAC[status]}} = 0.5 \cdot \left(\frac{m_{\text{SC03}}}{D_{\text{SC03}}}\right) + 0.5 \cdot \left(\frac{m_{\text{HFET}}}{D_{\text{HFET}}}\right)$$

Eq. 1066.845-1

Where:

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

D_{SC03} = measured driving distance during the SC03 test interval, in miles.

m_{HFET} = mass emissions from the HFET test interval, in grams.

D_{HFET} = measured driving distance during the HFET test interval, in miles.

(3) Calculate the incremental CO_2 emissions due to air conditioning operation by subtracting the composite mass-weighted emissions of CO_2 with the vehicle's air conditioner and the solar heating on, $e_{CO2\text{-}AC17compACon}$, from the composite mass-weighted emissions of CO_2 with the vehicle's air conditioner and the solar heating off, $e_{CO2\text{-}AC17compACoff}$.

(h) Record information for each test as specified in §1066.695. Emission results and the results of all calculations must be reported for each phase of the test. The manufacturer must also report the following information for each vehicle tested: interior volume, climate control system type and characteristics, refrigerant used, compressor type, and evaporator/condenser characteristics.

[79 FR 23823,Apr. 28, 2014, as amended at 79 FR 36658, June 30, 2014; 80 FR 9124, Feb. 19, 2015; 88 FR 4710, Jan. 24, 2023]

Subpart J—Evaporative Emission Test Procedures

§ 1066.901 Applicability and general provisions.

This subpart describes how to measure evaporative and refueling emissions from test vehicles. The provisions of §§1066.910 through 1066.930 include general provisions for equipment and calculations related to evaporative and refueling emissions. The provisions of §§1066.950 through 1066.985 describe provisions that apply specifically to motor vehicles subject to standards under 40 CFR part 86, subpart S, or 40 CFR part 1037.

TEST EQUIPMENT AND CALCULATIONS FOR EVAPORATIVE AND REFUELING EMISSIONS

§ 1066.910 SHED enclosure specifications.

Enclosures for evaporative and refueling emissions must meet the specifications described in 40 CFR 86.106–96, 86.107–96(a), and 86.107–98(a).

§ 1066.915 Enclosures; auxiliary systems and equipment.

Enclosures for evaporative and refueling emissions must be equipped with fans, blowers, and measurement and data recording equipment as described in 40 CFR 86.107–98(b) through (h) and (j).

§ 1066.920 Enclosure calibrations.

Enclosures for evaporative and refueling emissions must meet the calibration specifications described in 40 CFR 86.116–94 and 86.117–96.

§ 1066.925 Enclosure calculations for evaporative and refueling emissions.

Calculate emissions for evaporative emissions as described in 40 CFR 86.143–96. Calculate emissions for refueling emissions as described in 40 CFR 86.143–96 and 86.156–98.

§ 1066.930 Equipment for point-source measurement of running losses.

For point-source measurement of running loss emissions, use equipment meeting the specifications in 40 CFR 86.107–96(i).

[86 FR 34585, June 29, 2021]

EVAPORATIVE AND REFUELING EMISSION TEST PROCEDURES FOR MOTOR VEHICLES

§ 1066.950 Fuel temperature profile.

Develop fuel temperature profiles for running loss testing as described in 40 CFR 86.129–94(d).

§ 1066.955 Diurnal emission test.

Test vehicles for diurnal emissions as described in 40 CFR 86.133–96.

§ 1066.960 Running loss test.

Test vehicles for running loss emissions as described in 40 CFR 86.134–96.

§ 1066.965 Hot soak test.

Test vehicles for hot soak emissions as described in 40 CFR 86.138–96.

§ 1066.970 Refueling test for liquid fuels.

Except as described in § 1066.975, test vehicles for refueling emissions as described in 40 CFR 86.150–98, 86.151–98, 86.152–98, and 86.154–98. Keep records as described in 40 CFR 86.155–98.

§ 1066.971 Vehicle and canister preconditioning for the refueling test.

Precondition vehicles for the refueling emission test as described in 40 CFR 86.153–98.

§ 1066.975 Refueling test for LPG.

For vehicles designed to operate on liquefied petroleum gas, measure refueling emissions as described in 40 CFR 86.157–98.

§ 1066.980 Fuel dispensing spitback procedure.

Test vehicles for spitback emissions as described in 40 CFR 86.146–96.

§ 1066.985 Fuel storage system leak test procedure.

(a) *Scope*. Perform this test as required in the standard-setting part to verify that there are no significant leaks in your fuel storage system.

(b) *Measurement principles*. Leaks are detected by measuring pressure, temperature, and flow to calculate an equivalent orifice diameter for the system. Use good engineering judgment to develop and implement leak test equipment. You may not tighten fittings or connections in the vehicle's fuel system to prepare the vehicle for testing.

(c) *Measurement equipment*. Your leak test equipment must meet the following requirements:

(1) Pressure, temperature, and flow sensors must be calibrated with NIST-traceable standards.

(2) Correct flow measurements to standard reference conditions.

(3) Leak test equipment must have the ability to pressurize fuel storage systems to at least 4.1 kPa and have an internal leak rate of less than 0.20 standard liters per minute.

(4) You must be able to attach the test equipment to the vehicle without