Environmental Protection Agency § 1037.525

§ 1037.525 Special procedures for testing hybrid vehicles with power take-off.

This section describes the procedure for quantifying the reduction in greenhouse gas emissions as a result of running power take-off (PTO) devices with a hybrid powertrain. The procedures are written to test the PTO so that all the energy is produced with the engine. The full test for the hybrid vehicle is from a fully charged renewable energy storage system (RESS) to a depleted RESS and then back to a fully charged RESS. These procedures may be used for whole vehicles or with a post-transmission hybrid system. When testing just the post-transmission hybrid system, you must include all hardware for the PTO system. You may ask us to modify the provisions of this section to allow testing hybrid vehicles other than electric-battery hybrids, consistent with good engineering judgment.

(a) Select two vehicles for testing as follows:
(1) Select a vehicle with a hybrid powertrain to represent the vehicle family. If your vehicle family includes more than one vehicle model, use good engineering judgment to select the vehicle type with the maximum number of PTO circuits that has the smallest potential reduction in greenhouse gas emissions.
(2) Select an equivalent conventional vehicle as specified in §1037.615.

(b) Measure PTO emissions from the fully warmed-up conventional vehicle as follows:
(1) Without adding any additional restrictions, instrument the vehicle with pressure transducers at the outlet of the hydraulic pump for each circuit.
(2) Operate the PTO system with no load for at least 15 seconds. Measure the pressure and record the average value over the last 10 seconds (p_{\text{max}}). Apply maximum operator demand to the PTO system until the pressure relief valve opens and pressure stabilizes; measure the pressure and record the average value over the last 10 seconds (p_{\text{min}}).
(3) Denormalize the PTO duty cycle in appendix II of this part using the following equation:

\[ p_{\text{refi}} = NP_i \cdot \left( \frac{p_{\text{max}}}{p_{\text{min}}} \right) + p_{\text{min}} \]

Where:
- \( p_{\text{refi}} \) = the reference pressure at each point in the PTO cycle.
- \( NP_i \) = the normalized pressure at each point in the PTO cycle.
- \( p_{\text{max}} \) = the maximum pressure measured in paragraph (b)(2) of this section.
- \( p_{\text{min}} \) = the minimum pressure measured in paragraph (b)(2) of this section.

(4) If the PTO system has two circuits, repeat paragraph (b)(2) and (3) of this section for the second PTO circuit.
(5) Install a system to control pressures in the PTO system during the cycle.
(6) Start the engine.
(7) Operate the vehicle over one or both of the denormalized PTO duty cycles, as applicable. Collect CO\(_2\) emissions during operation over each duty cycle.
(8) Use the provisions of 40 CFR part 1066 to collect and measure emissions. Calculate emission rates in grams per test without rounding.
(9) For each test, validate the pressure in each circuit with the pressure specified from the cycle according to 40 CFR 1065.514. Measured pressures must meet the specifications in the following table for a valid test:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope, (</td>
<td>a_i</td>
</tr>
<tr>
<td>Absolute value of intercept, (</td>
<td>a_0</td>
</tr>
<tr>
<td>Standard error of estimate, SE(_E)</td>
<td>≤ 10% of maximum mapped pressure.</td>
</tr>
<tr>
<td>Coefficient of determination, ( r^2 )</td>
<td>≥ 0.970.</td>
</tr>
</tbody>
</table>

TABLE 1 OF § 1037.525—STATISTICAL CRITERIA FOR VALIDATING DUTY CYCLES
(10) Continue testing over the three vehicle drive cycles, as otherwise required by this part.
(11) Calculate combined cycle-weighted emissions of the four cycles as specified in paragraph (d) of this section.

(c) Measure PTO emissions from the fully warmed-up hybrid vehicle as follows:
(1) Perform the steps in paragraphs (b)(1) through (5) of this section.
(2) Prepare the vehicle for testing by operating it as needed to stabilize the battery at a full state of charge. For electric hybrid vehicles, we recommend running back-to-back PTO tests until engine operation is initiated to charge the battery. The battery should be fully charged once engine operation stops. The ignition should remain in the “on” position.
(3) Turn the vehicle and PTO system off while the sampling system is being prepared.
(4) Turn the vehicle and PTO system on such that the PTO system is functional, whether it draws power from the engine or a battery.
(5) Operate the vehicle over the PTO cycle(s) without turning the vehicle off, until the engine starts and then shuts down. The test cycle is completed once the engine shuts down. Measure emissions as described in paragraphs (b)(2) and (3) of this section.

Use good engineering judgment to minimize the variability in testing between the two types of vehicles.
(6) Refer to paragraph (b)(9) of this section for cycle validation.
(7) Continue testing over the three vehicle drive cycles, as otherwise required by this part.
(8) Calculate combined cycle-weighted emissions of the four cycles as specified in paragraph (d) of this section.

(d) Calculate combined cycle-weighted emissions of the four cycles for vocational vehicles as follows:
(1) Calculate the g/ton-mile emission rate for the driving portion of the test specified in §1037.510.
(2) Calculate the g/hr emission rate for the PTO portion of the test by dividing the total mass emitted over the cycle (grams) by the time of the test (hours). For testing where fractions of a cycle were run (for example, where three cycles are completed and the halfway point of a fourth PTO cycle is reached before the engine starts and shuts down again), use the following procedures to calculate the time of the test:
(i) Add up the time run for all complete tests.
(ii) For fractions of a test, use the following equation to calculate the time:

\[
\frac{\sum_{i=1}^{N} \left( N_{P_{i}} \cdot \frac{N_{P_{2}}}{\text{cycle}} \right) \cdot \Delta t}{\sum_{i=1}^{N} \left( N_{P_{i}} \cdot \frac{N_{P_{2}}}{\text{cycle}} \right) \cdot \Delta t}
\]

Where:
- \( t_{\text{test}} \) = time of the incomplete test.
- \( i \) = the number of each measurement interval.
- \( N \) = the total number of measurement intervals.
- \( N_{P_{1}} \cdot \frac{N_{P_{2}}}{\text{cycle}} \) = Normalized pressure command from circuit 1 of the PTO cycle.
- \( N_{P_{2}} \cdot \frac{N_{P_{2}}}{\text{cycle}} \) = Normalized pressure command from circuit 2 of the PTO cycle. Let \( N_{P_{2}} \cdot \frac{N_{P_{2}}}{\text{cycle}} = 1 \) if there is only one circuit.
- \( t_{\text{cycle}} \) = time of a complete cycle.

(iii) Sum the time from complete cycles (paragraph (d)(2)(i) of this section).

(3) Convert the g/hr PTO result to an equivalent g/mi value based on the assumed fraction of engine operating time during which the PTO is operating (28 percent) and an assumed average vehicle speed while driving (27.1 mph). The conversion factor is: Factor = \( 0.280 \cdot (1.000 - 0.280)/(27.1 \text{ mph}) = 0.0144 \text{ hr/mi} \). Multiply the g/hr emission rate by 0.0144 hr/mi.
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§ 1037.550 Special procedures for testing post-transmission hybrid systems.

This section describes the procedure for simulating a chassis test with a post-transmission hybrid system for A to B testing. The hardware that must be included in these tests is the engine, the transmission, the hybrid electric motor, the power electronics between the hybrid electric motor and the RESS, and the RESS. You may ask us to modify the provisions of this section to allow testing non-electric hybrid vehicles, consistent with good engineering judgment.

(1) Speed control. Program dynamometers using speed control as described in this paragraph (e)(1). We recommend speed control for automated manual transmissions or other designs where there is a power interrupt during shifts. Calculate the transmission output shaft’s angular speed target for the dynamometer, \( f_{\text{ref,dyno}} \), from the measured linear speed at the

\[
 f_{\text{ref,driver}} = \frac{S_{\text{cycle}} \cdot k_d}{2 \cdot \pi \cdot r}
\]

Where:
- \( S_{\text{cycle}} \) = vehicle speed of the test cycle for each point \( i \).
- \( k_d \) = final drive ratio (the angular speed of the transmission output shaft divided by the angular speed of the drive axle), as declared by the manufacturer.
- \( r \) = radius of the loaded tires, as declared by the manufacturer.

(e) Use either speed control or torque control to program the dynamometer to follow the test cycle, as follows: