an engineering analysis to verify an acceptable configuration, taking into account the maximum exhaust flow rate expected, the field test system’s flexible connectors, and the tubing’s characteristics for pressure drops versus flow.

(b) For vehicles or other motive equipment, we recommend installing PEMS in the same location where a passenger might sit. Follow PEMS manufacturer instructions for installing PEMS in cargo spaces, engine spaces, or externally such that PEMS is directly exposed to the outside environment. We recommend locating PEMS where it will be subject to minimal sources of the following parameters:

(1) Ambient temperature changes.
(2) Ambient pressure changes.
(3) Electromagnetic radiation.
(4) Mechanical shock and vibration.
(5) Ambient hydrocarbons—if using a FID analyzer that uses ambient air as FID burner air.

(c) Use mounting hardware as required for securing flexible connectors, ambient sensors, and other equipment. Use structurally sound mounting points such as vehicle frames, trailer hitch receivers, walk spaces, and payload tie-down fittings. We recommend mounting hardware such as clamps, suction cups, and magnets that are specifically designed for your application. We also recommend considering mounting hardware such as commercially available bicycle racks, trailer hitches, and luggage racks where applicable.

(d) Field testing may require portable electrical power to run your test equipment. Power your equipment, as follows:

(1) You may use electrical power from the vehicle, equipment, or vessel, up to the highest power level, such that all the following are true:

(i) The power system is capable of safely supplying power, such that the power demand for testing does not overload the power system.
(ii) The engine emissions do not change significantly as a result of the power demand for testing.
(iii) The power demand for testing does not increase output from the engine by more than 1% of its maximum power.

(2) You may install your own portable power supply. For example, you may use batteries, fuel cells, a portable generator, or any other power supply to supplement or replace your use of vehicle power. You may connect an external power source directly to the vehicle’s, vessel’s, or equipment’s power system; however, during a test interval (such as an NTE event) you must not supply power to the vehicle’s power system in excess of 1% of the engine’s maximum power.


§ 1065.915 PEMS instruments.

(a) Instrument specifications. We recommend that you use PEMS that meet the specifications of subpart C of this part. For unrestricted use of PEMS in a laboratory or similar environment, use a PEMS that meets the same specifications as each lab instrument it replaces. For field testing or for testing with PEMS in a laboratory or similar environment, under the provisions of §1065.905(b), the specifications in the following table apply instead of the specifications in Table 1 of §1065.205:

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Measurement quantity symbol</th>
<th>Rise time, $t_{10-90}$, and fall time, $t_{90-10}$,</th>
<th>Recording update frequency</th>
<th>Accuracy 1</th>
<th>Repeatability 1</th>
<th>Noise 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine speed transducer.</td>
<td>ns</td>
<td>1 s</td>
<td>1 Hz</td>
<td>5% of pt. or 1% of max.</td>
<td>2% of pt. or 1% of max.</td>
<td>0.5% of max.</td>
</tr>
<tr>
<td>Engine torque estimator, BSFC (This is a signal from an engine’s ECM)</td>
<td>T or BSFC</td>
<td>1 s</td>
<td>1 Hz</td>
<td>8% of pt. or 5% of max.</td>
<td>2% of pt. or 1% of max.</td>
<td>1% of max.</td>
</tr>
</tbody>
</table>

§ 1065.915 PEMS instruments.

(a) Instrument specifications. We recommend that you use PEMS that meet the specifications of subpart C of this part. For unrestricted use of PEMS in a laboratory or similar environment, use a PEMS that meets the same specifications as each lab instrument it replaces. For field testing or for testing with PEMS in a laboratory or similar environment, under the provisions of §1065.905(b), the specifications in the following table apply instead of the specifications in Table 1 of §1065.205:
Table 1 of §1065.915—Recommended Minimum PEMS Measurement Instrument Performance—Continued

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Measured quantity symbol</th>
<th>Rise time, ( t_{10\rightarrow90} ) and fall time, ( t_{90\rightarrow10} )</th>
<th>Recording update frequency</th>
<th>Accuracy (^1)</th>
<th>Repeatability (^1)</th>
<th>Noise (^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General pressure transducer (not a part of another instrument)</td>
<td>( p ) ................</td>
<td>5 s ................</td>
<td>1 Hz ................</td>
<td>5% of pt. or 5% of max.</td>
<td>2% of pt. or 0.5% of max.</td>
<td>1% of max.</td>
</tr>
<tr>
<td>Atmospheric pressure meter</td>
<td>( p_{\text{atm}} ) .....</td>
<td>50 s ..........</td>
<td>0.1 Hz ....</td>
<td>250 Pa .......... 200 Pa ..........</td>
<td>100 Pa.</td>
<td></td>
</tr>
<tr>
<td>General temperature sensor (not a part of another instrument)</td>
<td>( T ) ................</td>
<td>5 s ..........</td>
<td>1 Hz ........</td>
<td>1% of pt. K or 5 K</td>
<td>0.5% of pt. K or 2 K</td>
<td>0.5% of max 0.5 K.</td>
</tr>
<tr>
<td>General dewpoint sensor</td>
<td>( T_{\text{dew}} ) ......</td>
<td>50 s ..........</td>
<td>0.1 Hz ....</td>
<td>3 K .......... 1 K .......... 1 K.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exhaust flow meter</td>
<td>( n ) ................</td>
<td>1 s ..........</td>
<td>1 Hz ....means.</td>
<td>5% of pt. or 3% of max.</td>
<td>2% of pt. .......... 2% of max.</td>
<td></td>
</tr>
<tr>
<td>Dilution air, inlet air, exhaust, and sample flow meters</td>
<td>( n ) ................</td>
<td>1 s ..........</td>
<td>1 Hz ....means.</td>
<td>2.5% of pt. or 1.5% of max.</td>
<td>1.25% of pt. or 0.75% of max.</td>
<td></td>
</tr>
<tr>
<td>Continuous gas analyzer</td>
<td>( x ) ................</td>
<td>5 s ..........</td>
<td>1 Hz ........</td>
<td>4% of pt. or 4% of meas.</td>
<td>2% of pt. or 2% of meas.</td>
<td>1% of max.</td>
</tr>
<tr>
<td>Gravimetric PM balance</td>
<td>( m_{\text{PM}} ) ......</td>
<td>N/A ..........</td>
<td>N/A ..........</td>
<td>See §1065.790 ... 0.5 ( \mu ) g ..........</td>
<td>N/A.</td>
<td></td>
</tr>
<tr>
<td>Inertial PM balance</td>
<td>( m_{\text{PM}} ) ......</td>
<td>N/A ..........</td>
<td>N/A ..........</td>
<td>4% of pt. or 4% of meas.</td>
<td>2% of pt. or 2% of meas.</td>
<td>1% of max.</td>
</tr>
</tbody>
</table>

\(^1\) Accuracy, repeatability, and noise are all determined with the same collected data, as described in §1065.305, and based on absolute values. “pt.” refers to the overall flow-weighted mean value expected at the standard; “max.” refers to the peak value expected at the standard over any test interval, not the maximum of the instrument’s range; “meas” refers to the actual flow-weighted mean measured over any test interval.

(b) Redundant measurements. For all PEMS described in this subpart, you may use data from multiple instruments to calculate test results for a single test. If you use redundant systems, use good engineering judgment to use multiple measured values in calculations or to disregard individual measurements. Note that you must keep your results from all measurements, as described in §1065.25. This requirement applies whether or not you actually use the measurements in your calculations.

(c) Field-testing ambient effects on PEMS. We recommend that you use PEMS that are only minimally affected by ambient conditions such as temperature, pressure, humidity, physical orientation, mechanical shock and vibration, electromagnetic radiation, and ambient hydrocarbons. Follow the PEMS manufacturer’s instructions for proper installation to isolate PEMS from ambient conditions that affect their performance. If a PEMS is inherently affected by ambient conditions that you cannot control, you may monitor those conditions and adjust the PEMS signals to compensate for the ambient effect. The standard-setting part may also specify the use of one or more field-testing adjustments or measurement allowances that you apply to results or standards to account for ambient effects on PEMS.

(d) ECM signals. You may use signals from the engine’s electronic control module (ECM) in place of values measured by individual instruments within a PEMS, subject to the following provisions:

(1) Recording ECM signals. If your ECM updates a broadcast signal more or less frequently than 1 Hz, process data as follows:

(i) If your ECM updates a broadcast signal more frequently than 1 Hz, use PEMS to sample and record the signal’s value more frequently. Calculate and record the 1 Hz mean of the more frequently updated data.

(ii) If your ECM updates a broadcast signal less frequently than 1 Hz, use PEMS to sample and record the signal’s value at the most frequent rate. Linearly interpolate between recorded values and record the interpolated values at 1 Hz.
(iii) Optionally, you may use PEMS to electronically filter the ECM signals to meet the rise time and fall time specifications in Table 1 of this section. Record the filtered signal at 1 Hz.

(2) Omitting ECM signals. Replace any discontinuous or irrational ECM data with linearly interpolated values from adjacent data.

(3) Aligning ECM signals with other data. You must perform time-alignment and dispersion of ECM signals, according to PEMS manufacturer instructions and using good engineering judgment.

(4) ECM signals for determining test intervals. You may use any combination of ECM signals, with or without other measurements, to determine the start-time and end-time of a test interval.

(5) ECM signals for determining brake-specific emissions. You may use any combination of ECM signals, with or without other measurements, to estimate engine speed, torque, brake-specific fuel consumption (BSFC, in units of mass of fuel per kW-hr), and fuel rate for use in brake-specific emission calculations. We recommend that the overall performance of any speed, torque, or BSFC estimator should meet the performance specifications in Table 1 of this section. We recommend using one of the following methods:

(i) Speed. Use the engine speed signal directly from the ECM. This signal is generally accurate and precise. You may develop your own speed algorithm based on other ECM signals.

(ii) Torque. Use one of the following:

(A) ECM torque. Use the engine-torque signal directly from the ECM, if broadcast. Determine if this signal is proportional to indicated torque or brake torque. If it is proportional to indicated torque, subtract friction torque from indicated torque and record the result as brake torque. Friction torque may be a separate signal broadcast from the ECM or you may have to determine it from laboratory data as a function of engine speed.

(B) ECM %-load. Use the %-load signal directly from the ECM, if broadcast. Determine if this signal is proportional to indicated torque or brake torque. If it is proportional to indicated torque, subtract the minimum %-load value from the %-load signal. Multiply this result by the maximum brake torque at the corresponding engine speed. Maximum brake torque versus speed information is commonly published by the engine manufacturer.

(C) Your algorithms. You may develop and use your own combination of ECM signals to determine torque.

(iii) BSFC. Use one of the following:

(A) Use ECM engine speed and ECM fuel flow signals to interpolate brake-specific fuel consumption data, which might be available from an engine laboratory as a function of ECM engine speed and ECM fuel signals.

(B) Use a single BSFC value that approximates the BSFC value over a test interval (as defined in subpart K of this part). This value may be a nominal BSFC value for all engine operation determined over one or more laboratory duty cycles, or it may be any other BSFC that you determine. If you use a nominal BSFC, we recommend that you select a value based on the BSFC measured over laboratory duty cycles that best represent the range of engine operation that defines a test interval for field-testing. You may use the methods of this paragraph (d)(5)(iii)(B) only if it does not adversely affect your ability to demonstrate compliance with applicable standards.

(C) You may develop and use your own combination of ECM signals to determine BSFC.

(iv) ECM fuel rate. Use the fuel rate signal directly from the ECM and chemical balance to determine the molar flow rate of exhaust. Use §1065.655(d) to determine the carbon mass fraction of fuel. You may alternatively develop and use your own combination of ECM signals to determine fuel mass flow rate.

(v) Other ECM signals. You may ask to use other ECM signals for determining brake-specific emissions, such as ECM air flow. We must approve the use of such signals in advance.

(6) Permissible deviations. ECM signals may deviate from the specifications of this part 1065, but the expected deviation must not prevent you from demonstrating that you meet the applicable standards. For example, your emission results may be sufficiently below an applicable standard, such that the deviation would not significantly
change the result. As another example, a very low engine-coolant temperature may define a logical statement that determines when a test interval may start. In this case, even if the ECM’s sensor for detecting coolant temperature was not very accurate or repeatable, its output would never deviate so far as to significantly affect when a test interval may start.

§ 1065.920 PEMS calibrations and verifications.

(a) Subsystem calibrations and verifications. Use all the applicable calibrations and verifications in subpart D of this part, including the linearity verifications in §1065.307, to calibrate and verify PEMS. Note that a PEMS does not have to meet the system-response and updating-recording verifications of §1065.308 and 1065.309 if it meets the overall verification described in paragraph (b) of this section. This section does not apply to ECM signals.

(b) Overall verification. We require only that you maintain a record showing that the particular make, model, and configuration of your PEMS meets this verification. We recommend that you generate your own record to show that your specific PEMS meets this verification, but you may also rely on data and other information from the PEMS manufacturer. If you upgrade or change the configuration of your PEMS, your record must show that your new configuration meets this verification. The verification consists of operating an engine over a duty cycle in the laboratory and statistically comparing data generated and recorded by the PEMS with data simultaneously generated and recorded by laboratory equipment as follows:

(1) Mount an engine on a dynamometer for laboratory testing. Prepare the laboratory and PEMS for emission testing, as described in this part, to get simultaneous measurements. We recommend selecting an engine with emission levels close to the applicable duty-cycle standards, if possible.

(2) Select or create a duty cycle that has all the following characteristics:

(i) Engine operation that represents normal in-use speeds, loads, and degree of transient activity. Consider using data from previous field tests to generate a cycle.

(ii) A duration of (20 to 40) min.

(iii) At least 50% of engine operating time must include at least 10 valid test intervals for calculating emission levels for field testing. For example, for highway compression-ignition engines, select a duty cycle in which at least 50% of the engine operating time can be used to calculate valid NTE events.

(3) Starting with a warmed-up engine, run a valid emission test with the duty cycle from paragraph (b)(2) of this section. The laboratory and PEMS must both meet applicable validation requirements, such as drift validation, hydrocarbon contamination validation, and proportional validation.

(4) Determine the brake-specific emissions for each test interval for both laboratory and the PEMS measurements, as follows:

(i) For both laboratory and PEMS measurements, use identical values to determine the beginning and end of each test interval.

(ii) For both laboratory and PEMS measurements, use identical values to determine total work over each test interval.

(iii) If the standard-setting part specifies the use of a measurement allowance for field testing, also apply the measurement allowance during calibration using good engineering judgment. If the measurement allowance is normally added to the standard, this means you must subtract the measurement allowance from the measured PEMS brake-specific emission result.

(iv) Round results to the same number of significant digits as the standard.

(5) Repeat the engine duty cycle and calculations until you have at least 100 valid test intervals.

(6) For each test interval and emission, subtract the lab result from the PEMS result.

(7) The PEMS passes this verification if any one of the following are true for each constituent: