40 C.F.R. § 1065.510

Engine mapping.

(a) *Applicability, scope, and frequency.* An engine map is a data set that consists of a series of paired data points that represent the maximum brake torque versus engine speed, measured at the engine's primary output shaft. Map your engine if the standard-setting part requires engine mapping to generate a duty cycle for your engine configuration. Map your engine while it is connected to a dynamometer or other device that can absorb work output from the engine's primary output shaft according to § 1065.110. Configure any auxiliary work inputs and outputs such as hybrid, turbo-compounding, or thermoelectric systems to represent their in-use configurations, and use the same configuration for emission testing. See Figure 1 of § 1065.210. This may involve configuring initial states of charge and rates and times of auxiliary-work inputs and outputs. We recommend that you contact the EPA Program Officer before testing to determine how you should configure any auxiliary-work inputs and outputs. If your engine has an auxiliary emission control device to reduce torque output that may activate during engine mapping, turn it off before mapping. Use the most recent engine map to transform a normalized duty cycle from the standard-setting part to a reference duty cycle specific to your engine. Normalized duty cycles are specified in the standard-setting part. You may update an engine map at any time by repeating the engine-mapping procedure. You must map or re-map an engine before a test if any of the following apply:

(1) If you have not performed an initial engine map.

(2) If the atmospheric pressure near the engine's air inlet is not within ±5 kPa of the atmospheric pressure recorded at the time of the last engine map.

(3) If the engine or emission-control system has undergone changes that might affect maximum torque performance. This includes changing the configuration of auxiliary work inputs and outputs.

(4) If you capture an incomplete map on your first attempt or you do not complete a map within the specified time tolerance. You may repeat mapping as often as necessary to capture a complete map within the specified time.

(b) *Mapping variable-speed engines.* Map variable-speed engines using the procedure in this paragraph (b). Note that under § 1065.10(c) we may allow or require you to use "other procedures" if the specified procedure results in unrepresentative testing or if your engine cannot be tested using the specified procedure. If the engine has a user-adjustable idle speed setpoint, you may set it to its minimum adjustable value for this mapping procedure and the resulting map may be used for any test, regardless of where it is set for running each test.

(1) Record the atmospheric pressure.

(2) Warm up the engine by operating it. We recommend operating the engine at any speed and at approximately 75% of its expected maximum power. Continue the warm-up until the engine coolant, block, or

head absolute temperature is within ±2% of its mean value for at least 2 min or until the engine thermostat controls engine temperature.

(3) Operate the engine at its warm idle speed as follows:

(i) For engines with a low-speed governor, set the operator demand to minimum, use the dynamometer or other loading device to target a torque of zero on the engine's primary output shaft, and allow the engine to govern the speed. Measure this warm idle speed; we recommend recording at least 30 values of speed and using the mean of those values.

(ii) For engines without a low-speed governor, operate the engine at warm idle speed and zero torque on the engine's primary output shaft. You may use the dynamometer to target a torque of zero on the engine's primary output shaft, and manipulate the operator demand to control the speed to target the manufacturer-declared value for the lowest engine speed possible with minimum load (also known as manufacturer-declared warm idle speed). You may alternatively use the dynamometer to target the manufacturer-declared warm idle speed and manipulate the operator demand to control the torque on the engine's primary output shaft to zero.

(iii) For variable-speed engines with or without a low-speed governor, if a nonzero idle torque is representative of in-use operation, you may use the dynamometer or operator demand to target the manufacturer-declared idle torque instead of targeting zero torque as specified in paragraphs (b)(3)(i) and (ii) of this section. Control speed as specified in paragraph (b)(3)(i) or (ii) of this section, as applicable. If you use this option for engines with a low-speed governor to measure the warm idle speed with the manufacturer-declared torque at this step, you may use this as the warm-idle speed for cycle generation as specified in paragraph (b)(6) of this section. However, if you identify multiple warm idle torques under paragraph (f)(4)(i) of this section, measure the warm idle speed at only one torque level for this paragraph (b)(3).

(4) Operate the engine at the minimum mapped speed. A minimum mapped speed equal to (95 ±1)% of its warm idle speed determined in paragraph (b)(3) of this section may be used for any engine or test. A higher minimum mapped speed may be used if all the duty cycles that the engine is subject to have a minimum reference speed higher than the warm idle speed determined in paragraph (b)(3) of this section. In this case you may use a minimum mapped speed equal to (95 ±1)% of the lowest minimum reference speed in all the duty cycles the engine is subject to. Set operator demand to maximum and control engine speed at this minimum mapped speed for at least 15 seconds. Set operator demand to maximum and control engine speed at (95 ±1)% of its warm idle speed determined in paragraph (b)(3)(i) of this section for at least 15 seconds.

(5) Perform a continuous or discrete engine map as described in paragraphs (b)(5)(i) or (ii) of this section. A continuous engine map may be used for any engine. A discrete engine map may be used for engines subject only to steady-state duty cycles. Use linear interpolation between the series of points generated by either of these maps to determine intermediate torque values. Use the series of points generated by either of these maps to generate the power map as described in paragraph (e) of this section.

(i) For continuous engine mapping, begin recording mean feedback speed and torque at 1 Hz or more frequently and increase speed at a constant rate such that it takes (4 to 6) min to sweep from the minimum mapped speed described in paragraphs (b)(4) of this section to the check point speed described in paragraph (b)(5)(iii) of this section. Use good engineering judgment to determine when to stop recording data to ensure that the sweep is complete. In most cases, this means that you can stop the sweep at any point after the power falls to 50% of the maximum value.

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