§ 1065.610 Duty cycle generation.

This section describes how to generate duty cycles that are specific to your engine, based on the normalized duty cycles in the standard-setting part. During an emission test, use a duty cycle that is specific to your engine to command engine speed, torque, and power, as applicable, using an engine dynamometer and an engine operator demand. Paragraph (a) of this section describes how to ''normalize'' your engine's map to determine the maximum test speed and torque for your engine. The rest of this section describes how to use these values to ''denormalize'' the duty cycles in the standard-setting parts, which are all published on a normalized basis. Thus, the term ''normalized'' in paragraph (a) of this section refers to different values than it does in the rest of the section.

(a) *Maximum test speed, f_{ntest}.* This section generally applies to duty cycles for variable-speed engines. For constant-speed engines subject to duty cycles that specify normalized speed commands, use the no-load governed speed as the measured f_{ntest}. This is the highest engine speed where an engine outputs zero torque. For variable-speed engines, determine the measured f_{ntest} from the power-versus-speed map, generated according to § 1065.510, as follows:

(1) Based on the map, determine maximum power, P_{max}, and the speed at which maximum power occurred, f_{nPmax}. Divide every recorded power by P_{max} and divide every recorded speed by f_{nPmax}. The result is a normalized power-versus-speed map. Your measured f_{ntest} is the speed at which the sum of the squares of normalized speed and power is maximum, as follows:

$$f_{ntest} = f_{ni} \text{ at the maximum of } \left(f_{nnormi}^2 + P_{normi}^2\right) \quad \text{Eq. 1065.610-1}$$

Where:

f_{ntest} = maximum test speed.

i = an indexing variable that represents one recorded value of an engine map.

f_{nnormi} = an engine speed normalized by dividing it by f_{nPmax}.

P_{normi} = an engine power normalized by dividing it by P_{max}.

Example:

$(f_{nnorm1} = 1.002,\ P_{norm1} = 0.978,\ f_{n1} = 2359.71)$
$(f_{nnorm2} = 1.004,\ P_{norm2} = 0.977,\ fn_2 = 2364.42)$
$(f_{nnorm3} = 1.006,\ P_{norm3} = 0.974,\ f_{n3} = 2369.13)$
$(f_{nnorm1}^2 + P_{norm1}^2) = (1.002^2 + 0.978^2) = 1.960$
$(f_{nnorm1}^2 + P_{norm1}^2) = (1.004^2 + 0.977^2) = 1.963$
$(f_{nnorm1}^2 + P_{norm1}^2) = (1.006^2 + 0.974^2) = 1.961$
maximum = 1.963 at i = 2
f_{ntest} = 2364.42 rev/min

(2) For variable-speed engines, transform normalized speeds to reference speeds according to paragraph (c) of this section by using the measured maximum test speed determined according to paragraph (a)(1) of this section—or use your declared maximum test speed, as allowed in § 1065.510.

(3) For constant-speed engines, transform normalized speeds to reference speeds according to paragraph (c) of this section by using the measured no-load governed—speed or use your declared maximum test speed, as allowed in § 1065.510.

(b) *Maximum test torque, T_{test}.* For constant-speed engines, determine the measured T_{test} from the power-versus-speed map, generated according to § 1065.510, as follows:

(1) Based on the map, determine maximum power, P_{max}, and the speed at which maximum power occurs, f_{nPmax}. Divide every recorded power by P_{max} and divide every recorded speed by f_{nPmax}. The result is a normalized power-versus-speed map. Your measured T_{test} is the speed at which the sum of the squares of normalized speed and power is maximum, as follows:

$$T_{test} = T_i \text{ at the maximum of } \left(f_{nnormi}^2 + P_{normi}^2\right) \quad \text{Eq. 1065.610-2}$$

Where:

T_{test} = maximum test torque.

Example:

(f_{nnorm1} = 1.002, P_{norm1} = 0.978, T_1 = 722.62 N · m)
(f_{nnorm2} = 1.004, P_{norm2} = 0.977, T_2 = 720.44 N · m)
(f_{nnorm3} = 1.006, P_{norm3} = 0.974, T_3 = 716.80 N · m)
($f_{nnorm1}^2 + P_{norm1}^2$) = ($1.002_2 + 0.978_2$) = 1.960
($f_{nnorm1}^2 + P_{norm1}^2$) = ($1.004^2 + 0.977^2$) = 1.963
($f_{nnorm1}^2 + P_{norm1}^2$) = ($1.006^2 + 0.974^2$) = 1.961
maximum = 1.963 at i = 2
T_{test} = 720.44 Nm

(2) Transform normalized torques to reference torques according to paragraph (d) of this section by using the measured maximum test torque determined according to paragraph (b)(1) of this section—or use your declared maximum test torque, as allowed in § 1065.510.

(c) *Generating reference speed values from normalized duty cycle speeds.* Transform normalized speed values to reference values as follows:

(1) *% speed.* If your normalized duty cycle specifies % speed values, use your declared warm idle speed and your maximum test speed to transform the duty cycle, as follows:

$$f_{nref} = \%\ speed \cdot (f_{ntest} - f_{nidle}) + f_{nidle} \qquad \text{Eq. 1065.610-3}$$

Example:

% speed = 85 %
f_{ntest} = 2364 rev/min
f_{nidle} = 650 rev/min
f_{nref} = 85 % · (2364 650) + 650
f_{nref} = 2107 rev/min

(2) *A, B, and C speeds.* If your normalized duty cycle specifies speeds as A, B, or C values, use your power-versus-speed curve to determine the lowest speed below maximum power at which 50 % of maximum power occurs. Denote this value as n_{lo}. Also determine the highest speed above maximum power at which 70 % of maximum power occurs. Denote this value as n_{hi} Use n_{hi} and n_{lo} to calculate reference values for A, B, or C speeds as follows:

$$f_{nrefA} = 0.25 \cdot (n_{hi} - n_{lo}) + n_{lo} \qquad \text{Eq. 1065.610-4}$$

$$f_{nrefB} = 0.50 \cdot (n_{hi} - n_{lo}) + n_{lo} \qquad \text{Eq. 1065.610-5}$$

$$f_{nrefC} = 0.75 \cdot (n_{hi} - n_{lo}) + n_{lo} \qquad \text{Eq. 1065.610-6}$$

Example:

n_{lo} = 1005 rev/min
n_{hi} = 2385 rev/min
f_{nrefA} = 0.25 · (2385 1005) + 1005
f_{nrefB} = 0.50 · (2385 1005) + 1005
f_{nrefC} = 0.75 · (2385 1005) + 1005
f_{nrefA} = 1350 rev/min
f_{nrefB} = 1695 rev/min
f_{nrefC} = 2040 rev/min

(3) *Intermediate speed.* If your normalized duty cycle specifies a speed as ‘‘intermediate speed,’’ use your torque-versus-speed curve to determine the speed at which maximum torque occurs. This is peak torque speed. Identify your reference intermediate speed as one of the following values:

(i) Peak torque speed if it is between (60 and 75) % of maximum test speed.

(ii) 60% of maximum test speed if peak torque speed is less than 60% of maximum test speed.

(iii) 75% of maximum test speed if peak torque speed is greater than 75% of maximum test speed.

(d) *Generating reference torques from normalized duty-cycle torques.* Transform normalized torques to reference torques using your map of maximum torque versus speed.

(1) *Reference torque for variable-speed engines.* For a given speed point, multiply the corresponding % torque by the maximum torque at that speed, according to your map. Linearly interpolate mapped torque values to determine torque between mapped speeds. The result is the reference torque for each speed point.

(2) *Reference torque for constant-speed engines.* Multiply a % torque value by your maximum test torque. The result is the reference torque for each point. Note that if your constant-speed engine is subject to duty cycles that specify normalized speed commands, use the provisions of paragraph (d)(1) of this section to transform your normalized torque values.

(3) *Permissible deviations for any engine.* If your engine does not operate below a certain minimum torque under normal in-use conditions, you may use a declared minimum torque as the reference value instead of any value denormalized to be less than the declared value. For example, if your engine is connected to an automatic transmission, it may have a minimum torque called curb idle transmission torque (CITT). In this case, at idle conditions (i.e., 0% speed, 0% torque), you may use CITT as a reference value instead of 0 N·m.

(e) *Generating reference power values from normalized duty cycle powers.* Transform normalized power values to reference speed and power values using your map of maximum power versus speed.

(1) First transform normalized speed values into reference speed values. For a given speed point, multiply the corresponding % power by the maximum test power defined in the standard-setting part. The result is the reference power for each speed point. You may calculate a corresponding reference torque for each point and command that reference torque instead of a reference power.

(2) If your engine does not operate below a certain power under normal in-use conditions, you may use a declared minimum power as the reference value instead of any value denormalized to be less than the declared value. For example, if your engine is directly connected to a propeller, it may have a minimum power called idle power. In this case, at idle conditions (i.e., 0% speed, 0% power), you may use a corresponding idle power as a reference power instead of 0 kW.

§ 1065.630 1980 international gravity formula.

The acceleration of Earth's gravity, a_g, varies depending on your location. Calculate a_g at your latitude, as follows:

$$a_g = 9.7803267715 \cdot [1 + s\, 5.2790414 \cdot 10^{-3} \cdot \sin^2(\theta) + 2.32718 \cdot 10^{-5} \cdot \sin^4(\theta) + 1.262 \cdot 10^{-7} \cdot \sin^6(\theta) + 7 \cdot 10^{-10} \cdot \sin^8(\theta)] \quad \text{Eq. 1065.630-1}$$

Where:

θ = Degrees north or south latitude.

Example:

$\theta = 45°$

$a_g = 9.7803267715 \cdot (1 +$
$5.2790414 \cdot 10^{-3} \cdot \sin^2(45) +$
$2.32718 \cdot 10^{-5} \cdot \sin^4(45) +$
$1.262 \cdot 10^{-7} \cdot \sin^6(45) +$
$7 \cdot 10^{-10} \cdot \sin^8(45)$
$a_g = 9.8178291229$ m/s²

§ 1065.640 Flow meter calibration calculations.

This section describes the calculations for calibrating various flow meters. After you calibrate a flow meter using these calculations, use the calculations described in § 1065.642 to calculate flow during an emission test. Paragraph (a) of this section first describes how to convert reference flow meter outputs for use in the calibration equations, which are presented on a molar basis. The remaining paragraphs describe the calibration calculations that are specific to certain types of flow meters.

(a) *Reference meter conversions.* The calibration equations in this section use molar flow rate, $\dot{n}_{ref}$, as a reference quantity. If your reference meter outputs a flow rate in a different quantity, such as standard volume rate, $\dot{V}_{stdref}$, actual volume rate, $\dot{V}_{actref}$, or mass rate, $\dot{m}_{ref}$, convert your reference meter output to a molar flow rate using the following equations, noting that while