

motoring torque. For both maximum and motoring torque maps, linearly interpolate mapped torque values to determine torque between mapped speeds. If the reference speed is below the minimum mapped speed (*i.e.*, 95% of idle speed or 95% of lowest required speed, whichever is higher), use the mapped torque at the minimum mapped speed as the reference torque. 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.

(3) *Required deviations.* We require the following deviations for variable-speed engines intended primarily for propulsion of a vehicle with an automatic or manual transmission where that engine is subject to a transient duty cycle that specifies points with normalized reference speed of 0% and normalized reference torque of 0% (*i.e.*, idle points). These deviations are intended to produce a more representative transient duty cycle for these applications. For steady-state duty cycles or transient duty cycles with no idle operation, the requirements in this paragraph (d)(3) do not apply. Idle points for steady-state duty cycles of such engines are to be run at conditions simulating neutral or park on the transmission. For manual transmissions, set CITT to zero, which results in warm-idle-in-drive speed and torque values being the same as warm-idle-in-neutral values. For the case of a manual transmission where the optional declared idle torque in §1065.510(f)(5)(iii) and the optional declared power in §1065.510(f)(6) are not declared (*i.e.*, idle torque is zero), the required deviations in this paragraph (d)(3) have no impact and may be skipped.

(i) Determine the warm-idle-in-drive speed and torque values with the transmission in drive from the data collected during the engine mapping procedure in §1065.510. The warm-idle-in-drive torque is the sum of CITT and the torques representing loads from vehicle accessories. For example, the sum of the required declared CITT in §1065.510(f)(4), any optional declared torque in §1065.510(f)(5)(iii), and the

torque on the primary output shaft from any optional declared power in §1065.510(f)(6).

(ii) Determine the warm-idle-in-neutral speed and torque values with the transmission in neutral from the data collected during the engine mapping procedure in §1065.510. The warm-idle-in-neutral torque is the sum of any optional declared torque in §1065.510(f)(5)(iii) and the torque on the primary output shaft from any optional declared power in §1065.510(f)(6) (*i.e.*, the sum of the torques representing loads from vehicle accessories).

(iii) Zero-percent speed for denormalization of non-idle points is the warm-idle-in-drive speed.

(iv) For motoring points, make no changes.

(v) If the cycle begins with an idle segment (*i.e.*, a set of one or more contiguous idle points), set the reference speed and torque values to the warm-idle-in-neutral values for this initial segment. This is to represent idle operation with the transmission in neutral or park at the start of the transient duty cycle, after the engine is started. If the initial idle segment is longer than 24 seconds, change the reference speed and torque values for the remaining idle points in the initial idle segment to the warm-idle-in-drive values (*i.e.*, change idle points corresponding to 25 seconds to the end of the initial idle segment to warm-idle-in-drive). This is to represent manually shifting the transmission to drive.

(vi) For all other idle segments, set the reference speed and torque values to the warm-idle-in-drive values. This is to represent the transmission operating in drive.

(vii) If the engine is intended primarily for automatic transmissions with a Neutral-When-Stationary feature that automatically shifts the transmission to neutral after the vehicle is stopped for a designated time and automatically shifts back to drive when the operator increases demand (*i.e.*, pushes the accelerator pedal), reprocess all idle segments. Change reference speed and torque values from the warm-idle-in-drive values to the warm-idle-in-neutral values for idle

points in drive after the designated time.

(viii) For all nonidle nonmotoring points with normalized speed at or below zero percent and reference torque from zero to the warm-idle-in-drive torque value, set the reference torque to the warm-idle-in-drive torque value. This is to represent the transmission operating in drive.

(ix) For consecutive nonidle nonmotoring points that immediately follow and precede idle segments, with reference torque values from zero to the warm-idle-in-drive torque value, change their reference torques to the warm-idle-in-drive torque value. This is to represent the transmission operating in drive.

(x) For consecutive nonidle nonmotoring points that immediately follow and precede any point(s) that were modified in paragraph (d)(3)(viii) of this section, with reference torque values from zero to the warm-idle-in-drive torque value, change their reference torques to the warm-idle-in-drive torque value. This is to provide smooth torque transition around these points.

(4) *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 a hydrostatic transmission and it has a minimum torque even when all the driven hydraulic actuators and motors are stationary and the engine is at idle, then you may use this declared minimum torque as a reference torque value instead of any reference torque value generated under paragraph (d)(1) or (2) of this section that is between zero and this declared minimum torque.

(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 cor-

responding % power by the mapped power at maximum test speed, f_{ntest} , unless specified otherwise by the standard-setting part. The result is the reference power for each speed point, P_{ref} . Convert these reference powers to corresponding torques for operator demand and dynamometer control and for duty cycle validation per 1065.514. Use the reference speed associated with each reference power point for this conversion. As with cycles specified with % torque, linearly interpolate between these reference torque values generated from cycles with % power.

(2) Permissible deviations for any engine. 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, you may use this declared minimum power as a reference power value instead of any reference power value generated per paragraph (e)(1) of this section that is from zero to this declared minimum power.

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§ 1065.630 Local acceleration of gravity.

(a) The acceleration of Earth's gravity, a_g , varies depending on the test location. Determine a_g at your location by entering latitude, longitude, and elevation data into the U.S. National Oceanographic and Atmospheric Administration's surface gravity prediction website at https://geodesy.noaa.gov/cgi-bin/grav_pdx.prl.

(b) If the website specified in paragraph (a) of this section is unavailable, or the test location is outside of the continental United States, you may calculate a_g for your latitude as follows:

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

Eq. 1065.630-1

Where:

θ = Degrees north or south latitude.

Example:

$\theta = 45^\circ$

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

$$a_g = 9.8061992026 \text{ m/s}^2$$

[79 FR 23784, Apr. 28, 2014, as amended at 88 FR 4680, Jan. 24, 2023]

§ 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 values for volume rate, mass rate, pressure, temperature, and molar mass may change during an emission test, you should ensure that they are as constant as practical for each individual set point during a flow meter calibration:

$$\dot{n}_{ref} = \frac{\dot{V}_{stdref} \cdot p_{std}}{T_{std} \cdot R} = \frac{\dot{V}_{actref} \cdot p_{act}}{T_{act} \cdot R} = \frac{\dot{m}_{ref}}{M_{mix}}$$

Eq. 1065.640-1

Where:

\dot{n}_{ref} = reference molar flow rate.

\dot{V}_{stdref} = reference volume flow rate corrected to a standard pressure and a standard temperature.

\dot{V}_{actref} = reference volume flow rate at the actual pressure and temperature of the flow rate.

\dot{m}_{ref} = reference mass flow.

p_{std} = standard pressure.

p_{act} = actual pressure of the flow rate.

T_{std} = standard temperature.

T_{act} = actual temperature of the flow rate.

R = molar gas constant.

M_{mix} = molar mass of the flow rate.

Example 1:

$$\dot{V}_{stdref} = 1000.00 \text{ ft}^3/\text{min} = 0.471948 \text{ m}^3/\text{s}$$

$$p_{std} = 29.9213 \text{ in Hg @ } 32 \text{ }^\circ\text{F} = 101.325 \text{ kPa} = 101325 \text{ Pa} = 101325 \text{ kg}/(\text{m}\cdot\text{s}^2)$$

$$T_{std} = 68.0 \text{ }^\circ\text{F} = 293.15 \text{ K}$$

$$R = 8.314472 \text{ J}/(\text{mol}\cdot\text{K}) = 8.314472 \text{ (m}^2\cdot\text{kg)}/(\text{s}^2\cdot\text{mol}\cdot\text{K})$$

$$\dot{n}_{ref} = \frac{0.471948 \cdot 101325}{293.15 \cdot 8.314472}$$

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$\dot{n}_{\text{ref}} = 19.619 \text{ mol/s}$
Example 2:

$\dot{n}_{\text{ref}} = 17.2683 \text{ kg/min} = 287.805 \text{ g/s}$
 $M_{\text{mix}} = 28.7805 \text{ g/mol}$

$$\dot{n}_{\text{ref}} = \frac{287.805}{28.7805}$$

$\dot{n}_{\text{ref}} = 10.0000 \text{ mol/s}$

(b) *PDP calibration calculations.* 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 §1065.340 as follows:

$$V_{\text{rev}} = \frac{\bar{\dot{n}}_{\text{ref}} \cdot R \cdot \bar{T}_{\text{in}}}{\bar{P}_{\text{in}} \cdot \bar{f}_{\text{nPDP}}}$$

Eq. 1065.640-2

Where:

\dot{n}_{ref} = mean reference molar flow rate.
 R = molar gas constant.
 \bar{T}_{in} = mean temperature at the PDP inlet.
 \bar{P}_{in} = mean static absolute pressure at the PDP inlet.
 \bar{f}_{nPDP} = mean PDP speed.

Example:

$\dot{n}_{\text{ref}} = 25.096 \text{ mol/s}$
 $R = 8.314472 \text{ J}/(\text{mol}\cdot\text{K}) = 8.314472 \text{ (m}^2\cdot\text{kg)}/(\text{s}^2\cdot\text{mol}\cdot\text{K})$
 $\bar{T}_{\text{in}} = 299.5 \text{ K}$
 $\bar{P}_{\text{in}} = 98.290 \text{ kPa} = 98290 \text{ Pa} = 98290 \text{ kg}/(\text{m}\cdot\text{s}^2)$
 $\bar{f}_{\text{nPDP}} = 1205.1 \text{ r/min} = 20.085 \text{ r/s}$

$$V_{\text{rev}} = \frac{25.096 \cdot 8.314472 \cdot 299.5}{98290 \cdot 20.085}$$

$V_{\text{rev}} = 0.03166 \text{ m}^3/\text{r}$

(2) Calculate a PDP slip correction factor, K_s , for each restrictor position

from the mean values determined in §1065.340 as follows:

$$K_s = \frac{1}{\bar{f}_{\text{nPDP}}} \cdot \sqrt{\frac{\bar{P}_{\text{out}} - \bar{P}_{\text{in}}}{\bar{P}_{\text{out}}}}$$

Eq. 1065.640-3

Where:

\bar{f}_{nPDP} = 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:

$\bar{f}_{\text{nPDP}} = 1205.1 \text{ r/min} = 20.085 \text{ r/s}$
 $\bar{P}_{\text{out}} = 100.103 \text{ kPa}$
 $\bar{P}_{\text{in}} = 98.290 \text{ kPa}$