(2) You need not remap an engine according to paragraph (d) of this section. You need only verify the maximum torque or power at maximum test speed.

§ 1065.515 Test cycle generation.

(a) *Denormalizing test cycles.* The standard-setting parts establish the applicable test cycles consisting of second-by-second specifications for normalized torque and speed for transient cycles, or modal specifications for normalized torque and speed (or power and speed) for steady-state cycles. You must denormalize these values to get actual torque and speed for your engine.

(1) Torque is normalized to a maximum-torque value. Check the standard-setting part to see if it is normalized based on the maximum torque at the given speed or based on the maximum torque for all speeds. To denormalize the torque values in the cycle, use the engine's maximum-torque point or its torque map (§ 1065.510 describes how to generate the torque map).

(2) Power is normalized to a maximum-power value. Check the standard-setting part to see if it is normalized based on the maximum power at the given speed or based on the maximum power for all speeds. To denormalize the power values in the cycle, use the engine's maximum-power point or its power map (§ 1065.510 describes how to generate the power map).

(3) To denormalize speed, use the following equation:

Actual engine speed = (0.01) × (%engine speed) × (Maximum test speed—warm idle speed) + warm idle speed

(4) Paragraph (d) of this section describes how to calculate maximum test speed.

(b) *Example of denormalizing a test points.* For an engine with maximum test speed of 3800 rpm and warm idle speed of 600 rpm, denormalize the following test point: percent engine speed = 43, percent torque = 82.

(1) *Calculate actual engine speed.* The following equation applies for this example:

Actual engine speed = (0.01) × (43) × (3800 − 600) + 600 = 1976 rpm.

(2) *Determine actual torque.* Determine the maximum observed torque at 1976 rpm from the maximum torque curve. Then multiply this value (for example, 358 ft-lbs.) by 0.82. The resulting actual torque is 294 ft-lbs.

(c) *Cold-start enhancement devices.* If an engine has a properly operating automatic enhancement device for cold starts, let it override the zero-percent speed specified in the test cycles.

(d) *Maximum test speed.* For constant-speed engines, maximum test speed is the same as the engine's maximum operating speed in use. Maximum test speed for variable-speed engines occurs on the lug curve at the point farthest from the origin on a plot of power vs. speed. To find this speed, follow three main steps:

(1) *Generate the lug curve.* Before testing an engine for emissions, generate data points for maximum measured brake power with varying engine speed (see § 1065.510). These data points form the lug curve.

(2) *Normalize the lug curve.* To normalize the lug curve, do three things:

(i) Identify the point (power and speed) on the lug curve where maximum power occurs.

(ii) Normalize the power values of the lug curve—divide them by the maximum power and multiply the resulting values by 100.

(iii) Normalize the engine speed values of the lug curve—divide them by the speed at which maximum power occurs and multiply the resulting values by 100.

(3) *Determine maximum test speed.* Calculate the maximum test speed from the following speed-factor analysis:

(i) For a given power-speed point, the speed factor is the normalized distance to the power-speed point from the zero-power, zero-speed point. Compute the speed factor's value:

$$\text{Speed factor} = \sqrt{(\text{power})^2 + (\text{speed})^2}$$

(ii) Determine the maximum value of speed factors for all the power-speed data points on the lug curve. Maximum test speed is the speed at which the speed factor's maximum value occurs. Note that this maximum test speed is

the 100-percent speed point for normalized transient duty cycles.

(e) *Intermediate test speed.* Determine intermediate test speed with the following provisions:

(1) If peak torque speed is 60 to 75 percent of the maximum test speed, the intermediate speed point is at that same speed.

(2) If peak torque speed is less than 60 percent of the maximum test speed, the intermediate speed point is at 60 percent of maximum test speed.

(3) If peak torque speed is greater than 75 percent of the maximum test speed, the intermediate speed point is at 75 percent of maximum test speed.

§ 1065.520 Engine starting, restarting, and shutdown.

Unless the standard-setting part specifies otherwise, follow the steps in this section to start and shut down the test engine:

(a) *Engine starting.* Start the engine according to the manufacturer's recommended starting procedure in the owner's manual, using either a production starter motor or the dynamometer. Use the dynamometer to crank (or motor) the engine at the typical in-use cranking speed with a fully charged battery (nominal speed ±10 percent), accelerating the engine to cranking speed in the same time it would take with a starter motor (nominal ±0.5 seconds). Stop motoring by the dynamometer within one second of starting the engine. The cycle's free-idle period begins when you determine that the engine has started.

(1) If the engine does not start after 15 seconds of cranking, stop cranking and determine the reason it failed to start. While diagnosing the problem, turn off the device that measures gas flow (or revolution counter) on the constant-volume sampler (and all integrators when measuring emissions continuously). Also, turn off the constant-volume sampler or disconnect the exhaust tube from the tailpipe. If failure to start is an operational error, reschedule the engine for testing (this may require soaking the engine if the test requires a cold-start).

(2) If longer cranking times are necessary, you may use them instead of the 15-second limit, as long as the owner's manual and the service-repair manual describe the longer cranking times as normal.

(3) If an engine malfunction causes a failure to start, you may correct it in less than 30 minutes and continue the test. Reactivate the sampling system at the same time cranking begins. When the engine starts, begin the timing sequence. If an engine malfunction causes a failure to start, and you cannot restart the engine, the test is void.

(b) *Engine stalling.* Respond to engine stalling as follows:

(1) If the engine stalls during the warm-up period, the initial idle period of test, or the steady-state segment, you may restart the engine immediately using the appropriate starting procedure and continue the test.

(2) If the engine stalls at any other time, the test is void.

(c) *Engine shutdown.* Shut the engine down according to the manufacturer's specifications.

§ 1065.525 Engine dynamometer test run.

Take the following steps for each test:

(a) Prepare the engine, dynamometer, and sampling system. Change filters or other replaceable items and check for leaks as necessary.

(b) If you are using bag samples, connect evacuated sample-collection bags to the collection system for the dilute exhaust and dilution air sample.

(c) Attach the CVS to the engine's exhaust system any time before starting the CVS.

(d) Start the CVS (if not already started), the sample pumps, the engine cooling fans, and the data-collection system. Before the test begins, preheat the CVS's heat exchanger (if used) and the heated components of any continuous sampling systems to designated operating temperatures.

(e) Adjust the sample flow rates to the desired levels and set to zero the devices in the CVS that measure gas flow. The venturi design fixes the sample flow rate in a CFV–CVS.

(f) Start the engine if engine starting is not part of the test cycle, as specified in the standard-setting part.