(v) The torque curve resulting from paragraphs (e)(1) (i) through (iv) of this section is the mapping curve and will be used to convert the normalized torque values in the engine cycle (*see* paragraph (f)(1) of appendix I to this part) to actual torque values for the test cycle.

(2) *Diesel engines.* (i) Connect all data points recorded under paragraph (d)(3)(vi) of this section using linear interpolation between points.

(ii) For governed engines, all points above the maximum speed (*see* paragraph (c)(2)(ii) of this section) shall be assigned maximum torque values of zero for purposes of cycle generation.

(iii) For all engines, all speed points below the minimum speed shall be assigned a maximum torque value equal to that observed at the minimum speed for purposes of cycle generation.

(iv) The torque curve resulting from paragraphs (e)(2) (i) through (iii) of this section is the mapping curve and will be used to convert the normalized torque values in the engine cycle (*see* paragraph (f)(2) of appendix I to this part) into actual torque values for the test cycle.

(f) *Alternate mapping.* If a manufacturer believes that the above mapping techniques are unsafe or unrepresentative for any given engine or engine family, alternate mapping techniques may be used. These alternate techniques must satisfy the intent of the specified mapping procedures to determine the maximum available torque at all engine speeds achieved during the test cycles. Deviations from the mapping techniques specified in this section for reasons of safety or representativeness shall be reported per § 86.1344(e)(6), along with the justification for their use. In no case, however, shall descending continual sweeps of rpm be used for governed or turbocharged engines.

(g) *Replicate Tests.* An engine need not be mapped before each and every cold cycle test. An engine shall be remapped prior to a cold cycle test if:

(1) An unreasonable amount of time has transpired since the last map, as determined by engineering judgment, or

(2) The barometric pressure prior to the start of the cold cycle test has changed more than 1 in hg. from the average barometric pressure observed during the map, or

(3) Physical changes or recalibrations have been made to the engine which may potentially affect engine performance.

[54 FR 14597, Apr. 11, 1989, as amended at 59 FR 48533, Sept. 21, 1994]

§ 86.1333–90 Transient test cycle generation.

(a) The heavy-duty transient engine cycles for Otto-cycle and diesel engines are listed in appendix I ((f) (1), (2) and (3)) to this part. These second-by-second listings represent torque and rpm maneuvers characteristic of heavy-duty engines. Both rpm and torque are normalized (expressed as a percentage of maximum) in these listings.

(1) To unnormalize rpm, use the following equation:

$$\text{Actual rpm} = \frac{\%\ \text{rpm}\ (\text{Measured rated rpm} - \text{Curb idle rpm})}{100} + \text{Curb idle rpm}$$

The method of calculating measured rated rpm is detailed in paragraph (g) of this section.

(2) Torque is normalized to the maximum torque at the rpm listed with it. Therefore, to unnormalize the torque values in the cycle, the maximum torque curve for the engine in question must be used. The generation of the maximum torque curve is described in § 86.1332.

(3) The EPA Engine Dynamometer Schedule for Heavy Duty Diesel Engines listed in appendix I (f)(2) contains torque points referred to as ‘‘closed rack motoring.’’ For reference cycle calculation torque points shall take on unnormalized values determined in either of the following three ways:

(i) Negative 40 percent of the positive torque available at the associated speed point. The generation of this positive maximum torque curve is described in § 86.1332.

(ii) Map the amount of negative torque required to motor the engine between idle and maximum mapping speed and use this map to determine the amount of negative torque required at the associated speed point.

(iii) Determine the amount of negative torque required to motor the engine at idle and rated speeds and linearly interpolate using these two points.

(b) *Example of the unnormalization procedure.* The following test point shall be unnormalized:

Percent RPM	Percent Torque
43	82

Given the following values:

Measured Rated rpm = 3800.

Curb Idle rpm = 600.

(1) *Calculate actual rpm:*

$$\text{Actual rpm} = \frac{\%\ \text{rpm (measured rated rpm} - \text{curb idle rpm)}}{100} + \text{curb idle rpm}$$

$$= \frac{43\,(3800 - 600)}{100} + 600$$

$$= \frac{43\,(3800 - 600)}{1976} + 600$$

(2) *Determine actual torque:* Determine the maximum observed torque at 1976 rpm from the maximum torque curve. Then multiply this value (*e.g.*, 358 ft-lbs) by 0.82. This results in an actual torque of 294 ft-lbs.

(c) Engine speed and torque shall be recorded at least once every second during the cold start test and hot start test. The torque and rpm feedback signals may be filtered.

(d) Idle Speed Enhancement Devices (*e.g.* cold idle, alternator idle, etc.). For an engine equipped with an idle speed enhancement device, the zero percent speed specified in the engine dynamometer schedules (appendix I (f)(1), (f)(2), or (f)(3) to this part) does not apply. The idle speed shall be the speed that results from the proper operation of the engine's idle speed enhancement device.

(1) During idle speed enhancement device operation, a manual transmission engine shall be allowed to idle at whatever speed is required to target a feedback torque equal to zero (using, for example, clutch disengagement, speed to torque control switching, software overrides, etc.) at those points in appendix I(f)(1), (f)(2), or (f)(3) to this part where both reference speed and reference torque are zero percent values. For each idle segment that is ten seconds or longer, the average feedback torque must be within ±10 ft-lbs of zero. To allow for transition, up to the first four seconds may be deleted from each idle segment calculation.

(2) During idle speed enhancement device operation, an automatic transmission engine shall be allowed to idle at whatever speed is required to target a feedback torque equal to CITT (see paragraph (e)(2) of this section for definition of CITT) at those points in appendix I(f)(1), (f)(2), or (f)(3) to this part where both reference speed and reference torque are zero percent values. For each idle segment that is ten seconds or longer, the average feedback torque must be within ±10 ft-lbs of CITT. To allow for transition, up to the first four seconds may be deleted from each idle segment calculation.

(e) *Automatic transmissions.* The reference cycles in paragraphs (f) (1) and (2) of appendix I to this part shall be altered for test engines intended primarily for use with automatic transmissions.

(1) Zero percent speed for automatic transmission engines is defined as curb idle rpm (*i.e.*, in-vehicle, coupled with automatic transmission in gear).

(2) All zero-percent speed, zero-percent torque points (idle points) shall be

modified to zero percent speed, Curb Idle Transmission Torque (CITT), except as permitted in § 86.1337–90(a)(9). Also, all points with speed equal to or less than zero percent and torque less than CITT shall be modified to CITT. Motoring torque shall remain unchanged. In order to provide a smooth torque transition, all consecutive torque points that are between 0 and CITT shall be changed to CITT if the first of these is preceded or the last of these is succeeded by idle points. The manufacturer's specified CITT shall be based upon that value observed in typical applications at the mean of the manufacturers' specified idle speed range at stabilized temperature conditions.

(f) *Clutch operation*. Manual transmission engines may be tested with a clutch. If used, the clutch shall be disengaged at all zero percent speeds, zero percent torque points, but may be engaged up to two points preceeding a non-zero point, and may be engaged for time segments with zero percent speed and torque points of durations less than four seconds. (*See* § 86.1341 for allowances in the cycle validation criteria.)

(g) *Measured rated rpm*. The measured rated rpm corresponds to the 100 percent rpm values specified in the reference cycles (paragraphs (f) (1) and (2) of appendix I to this part). It is generally intended to represent the rpm at which maximum brake horsepower occurs. For the purposes of this test sequence, it shall either be defined as the manufacturer's specified rated speed, or calculated in the following way, whichever yields the higher speed:

(1) From the maximum torque curve generated per § 86.1332, find the maximum observed brake horsepower of the engine.

(2) Calculate 98 percent of the observed maximum brake horsepower, and determine from the maximum torque curve the highest and lowest engine rpms at which this brake horsepower is observed.

(3) The highest and lowest of the 98 percent power rpms represent the endpoints of an rpm range. The midpoint of this range shall be considered the measured rated rpm for cycle generation purposes.

[54 FR 14599, Apr. 11, 1989, as amended at 62 FR 47131, Sept. 5, 1997; 63 FR 24449, May 4. 1998; 65 FR 8279, Feb. 18, 2000]

§ 86.1333–2010 Transient test cycle generation.

(a) *Generating transient test cycles*. The heavy-duty transient engine cycles for Otto-cycle and diesel engines are listed in Appendix I((f) (1), (2) and (3)) to this part. These second-by-second listings represent torque and rpm maneuvers characteristic of heavy-duty engines. Both rpm and torque are normalized (expressed as a percentage of maximum) in these listings.

(1) To unnormalize rpm, use the following equations:

(i) For diesel engines:

$$\text{Actualrpm} = \frac{\%\text{rpm} \cdot (\text{MaxTestSpeed} - \text{CurbIdleSpeed})}{112} + \text{CurbIdleSpeed}$$

Where:

MaxTestSpeed = the maximum test speed as calculated in 40 CFR part 1065.

(ii) For Otto-cycle engines:

$$\text{Actualrpm} = \frac{\%\text{rpm} \cdot (\text{MaxTestSpeed} - \text{CurbIdleSpeed})}{112} + \text{CurbIdleSpeed}$$

Where:

MaxTestSpeed = the maximum test speed as calculated in 40 CFR part 1065.