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ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 9, 59, 60, 85, 86, 88, 89, 90, 91, 92, 94, 1027, 1033, 1036, 1037, 1039, 1042, 1043, 1045, 1048, 1051, 1054, 1060, 1065, 1066, 1068, and 1074

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RIN 2060-AU62

Improvements for Heavy-Duty Engine and Vehicle Test Procedures, and other Technical Amendments

Correction

In rule document 2021-05306, appearing on pages 34308-34590, in the issue of Tuesday, June 29, 2021, make the following corrections:

§ 1037.565 [Corrected]

1. On page 34486, beginning in the first column, Section 1037.565 is corrected to read as follows:

§ 1037.565 Transmission efficiency test.

This section describes a procedure for mapping transmission efficiency through a

determination of transmission power loss.

(a) You may establish transmission power loss maps based on testing any number of

transmission configurations within a transmission family as specified in §1037.232. You

may share data across any configurations within the family, as long as you test the

transmission configuration with the lowest efficiency from the transmission family.

Alternatively, you may ask us to approve analytically derived power loss maps for

untested configurations within the same transmission family (see §1037.235(h)).

(b) Prepare a transmission for testing as follows:

   (1) Select a transmission with less than 500 hours of operation before testing.

   (2) Mount the transmission to the dynamometer such that the geared shaft in the

   transmission is aligned with the input shaft from the dynamometer.

(3) Add transmission oil according to the transmission manufacturer's instructions. If the transmission manufacturer specifies multiple transmission oils, select the one with the highest viscosity at operating temperature. You may use a lower-viscosity transmission oil if we approve it as critical emission-related maintenance under §1037.125. Fill the transmission oil to a level that represents in-use operation. You may use an external transmission oil conditioning system, as long as it does not affect measured values.

(4) Include any internal and external pumps for hydraulic fluid and lubricating oil in the test. Determine the work required to drive an external pump according to 40 CFR 1065.210.

(5) Install equipment for measuring the bulk temperature of the transmission oil in the oil sump or a similar location.

(6) If the transmission is equipped with a torque converter, lock it for all testing performed in this section.

(7) Break in the transmission using good engineering judgment. Maintain transmission oil temperature at (87 to 93) °C for automatic transmissions and transmissions having more than two friction clutches, and at (77 to 83) °C for all other transmissions. You may ask us to approve a different range of transmission oil temperatures if you have data showing that it better represents in-use operation.

(c) Measure input and output shaft speed and torque as described in 40 CFR 1065.210(b). You must use a speed measurement system that meets an accuracy of ±0.05 % of point. Accuracy requirements for torque transducers depend on the highest loaded transmission input and output torque as described in paragraph (d)(2) of this section. Use torque

transducers for torque input measurements that meet an accuracy requirement of ±0.2 %

of the highest loaded transmission input for loaded test points and ±0.1 % of the highest

loaded transmission input torque for unloaded test points. For torque output

measurements, torque transducers must meet an accuracy requirement of ±0.2 % of the

highest loaded transmission output torque for each gear ratio. Calibrate and verify

measurement instruments according to 40 CFR part 1065, subpart D. Command speed

and torque at a minimum of 10 Hz, and record all data, including bulk oil temperature, at

a minimum of 1 Hz mean values.

(d) Test the transmission at input shaft speeds and torque setpoints as described in this

paragraph (d). You may exclude lower gears from testing; however, you must test all the

gears above the highest excluded gear. GEM will use default values for any untested

gears. The test matrix consists of test points representing transmission input shaft speeds

and torque setpoints meeting the following specifications for each tested gear:

   (1) Test at the following transmission input shaft speeds:

      (i) 600.0 r/min or transmission input shaft speed when paired with the engine

      operating at idle.

      (ii) The transmission's maximum rated input shaft speed. You may alternatively

      select a value representing the highest expected in-use transmission input shaft

      speed.

      (iii) Three equally spaced intermediate speeds. The intermediate speed points

      may be adjusted to the nearest 50 or 100 r/min. You may test any number of

      additional speed setpoints to improve accuracy.

   (2) Test at certain transmission input torque setpoints as follows:

(i) Include one unloaded (zero-torque) setpoint.

(ii) Include one loaded torque setpoint between 75 % and 105 % of the transmission's maximum rated input shaft torque. However, you may use a lower torque setpoint as needed to avoid exceeding dynamometer torque limits, as long as testing accurately represents in-use performance. If your loaded torque setpoint is below 75 % of the transmission's maximum rated input shaft torque, you must demonstrate that the sum of time for all gears where demanded engine torque is between your maximum torque setpoint and 75 % of the transmission's maximum rated input shaft torque is no more than 10 % of the time for each vehicle drive cycle specified in this subpart. This demonstration must be made available upon request.

(iii) You may test at any number of additional torque setpoints to improve accuracy.

(iv) Note that GEM calculates power loss between tested or default values by linear interpolation, except that GEM may extrapolate outside of measured values to account for testing at torque setpoints below 75 % as specified in paragraph (d)(2)(ii) of this section.

(3) In the case of transmissions that automatically go into neutral when the vehicle is stopped, also perform tests at 600 r/min and 800 r/min with the transmission in neutral and the transmission output fixed at zero speed.

(e) Determine transmission efficiency using the following procedure:

(1) Maintain ambient temperature between (15 and 35) °C throughout testing. Measure ambient temperature within 1.0 m of the transmission.

(2) Maintain transmission oil temperature as described in paragraph (b)(7) of this section.

(3) Use good engineering judgment to warm up the transmission according to the transmission manufacturer's specifications.

(4) Perform unloaded transmission tests by disconnecting the transmission output shaft from the dynamometer and letting it rotate freely. If the transmission adjusts pump pressure based on whether the vehicle is moving or stopped, set up the transmission for unloaded tests to operate as if the vehicle is moving.

(5) For transmissions that have multiple configurations for a given gear ratio, such as dual-clutch transmissions that can pre-select an upshift or downshift, set the transmission to operate in the configuration with the greatest power loss. Alternatively, test in each configuration and use good engineering judgment to calculate a weighted power loss for each test point under this section based on field data that characterizes the degree of in-use operation in each configuration.

(6) For a selected gear, operate the transmission at one of the test points from paragraph (d) of this section for at least 10 seconds. Measure the speed and torque of the input and output shafts for at least 10 seconds. You may omit measurement of output shaft speeds if your transmission is configured to not allow slip. Calculate arithmetic mean values for mean input shaft torque, $\overline{T}_{in}$, mean output shaft torque, $\overline{T}_{out}$, mean input shaft speed, $\overline{f}_{nin}$, and mean output shaft speed, $\overline{f}_{nout}$, for each point in the test matrix for each test. Repeat this stabilization, measurement, and calculation for the other speed and torque setpoints from the test matrix for the

selected gear in any sequence. Calculate power loss as described in paragraph (f) of this section based on mean speed and torque values at each test point.

(7) Repeat the procedure described in paragraph (e)(6) of this section for all gears, or for all gears down to a selected gear. This section refers to an "operating condition" to represent operation at a test point in a specific gear.

(8) Perform the test sequence described in paragraphs (e)(6) and (7) of this section three times. You may do this repeat testing at any given test point before you perform measurements for the whole test matrix. Remove torque from the transmission input shaft and bring the transmission to a complete stop before each repeat measurement.

(9) You may need to perform additional testing at a given operating condition based on a calculation of a confidence interval to represent repeatability at a 95 % confidence level at that operating condition. If the confidence interval is greater than 0.10 % for loaded tests or greater than 0.05 % for unloaded tests, perform another measurement at that operating condition and recalculate the repeatability for the whole set of test results. Continue testing until the confidence interval is at or below the specified values for all operating conditions. As an alternative, for any operating condition that does not meet this repeatability criterion, you may determine a maximum power loss instead of calculating a mean power loss as described in paragraph (g) of this section. Calculate a confidence interval representing the repeatability in establishing a 95 % confidence level using the following equation:

$$Confidence\ Interval = \frac{1.96 \cdot \sigma_{Ploss}}{\sqrt{N} \cdot P_{rated}} \cdot 100\ \%$$

 Eq. 1037.565-1

Where:

σ_{Ploss} = standard deviation of power loss values at a given operating condition (see 40 CFR 1065.602(c)).

N = number of repeat tests for an operating condition.

P_{rated} = the transmission's rated input power for a given gear. For testing in neutral, use the value of P_{rated} for the top gear.

Example:

σ_{Ploss} = 0.1200 kW

$N = 3$

P_{rated} = 314.2000 kW

$$Confidence\ Interval = \frac{1.96 \cdot 0.1650}{\sqrt{3} \cdot 314.2000} \cdot 100\ \%$$

Confidence Interval = 0.0432 %

(f) Calculate the mean power loss, $\overline{\overline{P}}_{loss}$, at each operating condition as follows:

(1) Calculate $\overline{P}_{loss}$ for each measurement at each operating condition as follows:

$$\overline{P}_{loss} = \overline{T}_{in} \cdot \overline{f}_{nin} - \overline{T}_{out} \cdot \overline{f}_{nout}$$

Eq. 1037.565-2

Where:

$\overline{T}_{in}$ = mean input shaft torque from paragraph (e)(6) of this section.

$\overline{f}_{nin}$ = mean input shaft speed from paragraph (e)(6) of this section in rad/s.

$\overline{T}_{out}$ = mean output shaft torque from paragraph (e)(6) of this section. Let $\overline{T}_{out} = 0$ for all unloaded tests.

$\overline{f}_{\text{nout}}$ = mean output shaft speed from paragraph (e)(6) of this section in rad/s. Let

$\overline{f}_{\text{nout}} = 0$ for all tests with the transmission in neutral. See paragraph (f)(2) of this

section for calculating $\overline{f}_{\text{nout}}$ as a function of $\overline{f}_{\text{nin}}$ instead of measuring f_{nout}.

(2) For transmissions that are configured to not allow slip, you may calculate $\overline{f}_{\text{nout}}$

based on the gear ratio using the following equation:

$$\overline{f}_{\text{nout}} = \frac{\overline{f}_{\text{nin}}}{k_{\text{g}}}$$

Eq. 1037.565-3

Where:

k_{g} = transmission gear ratio, expressed to at least the nearest 0.001.

(3) Calculate $\overline{\overline{P}}_{\text{loss}}$ as the mean power loss from all measurements at a given operating

condition.

(4) The following example illustrates a calculation of $\overline{\overline{P}}_{\text{loss}}$:

$\overline{T}_{\text{in1}} = 1000.0$ N·m

$\overline{f}_{\text{nin,1}} = 1000$ r/min = 104.72 rad/sec

$\overline{T}_{\text{out,1}} = 2654.5$ N·m

$\overline{f}_{\text{nout,1}} = 361.27$ r/min = 37.832 rad/s

$\overline{P}_{\text{loss,1}} = 1000.0 \cdot 104.72 - 2654.5 \cdot 37.832$

$\overline{P}_{\text{loss,1}} = 4295$ W = 4.295 kW

$$\overline{\overline{P}}_{loss,2} = 4285 \text{ W} = 4.285 \text{ kW}$$

$$\overline{\overline{P}}_{loss,3} = 4292 \text{ W} = 4.292 \text{ kW}$$

$$\overline{\overline{\overline{P}}}_{loss} = \frac{4.295 + 4.285 + 4.292}{3} = 4.291 \text{ kW}$$

(g) Create a table with the mean power loss, $\overline{\overline{\overline{P}}}_{loss}$, corresponding to each operating condition for input into GEM. Also include power loss in neutral for each tested engine's speed, if applicable. Express transmission input speed in r/min to one decimal place; express input torque in N·m to two decimal places; express power loss in kW to four decimal places. Record the following values:

(1) Recored $\overline{\overline{\overline{P}}}_{loss}$, $\overline{\overline{\overline{T}}}_{in}$, and $\overline{\overline{\overline{f}}}_{nin}$ for each operating condition meeting the repeatability criterion in in paragraph (e)(9) of this section. Calculate $\overline{\overline{\overline{T}}}_{in}$ and $\overline{\overline{\overline{f}}}_{nin}$ for each operating condition by calculating the arithmetic average of $\overline{\overline{T}}_{in}$ and $\overline{\overline{f}}_{nin}$ for all the repeat tests at that operating condition.

(2) For any operating condition not meeting the repeatability criterion in paragraph (e)(9) of this section, record the maximum value of $\overline{\overline{P}}_{loss}$ for that operating condition along with the corresponding values of $\overline{\overline{T}}_{in}$ and $\overline{\overline{f}}_{nin}$.

(h) Record declared power loss values at or above the corresponding value calculated in paragraph (f) of this section. Use good engineering judgment to select values that will be at or above the mean power loss values for your production transmissions. Vehicle manufacturers will use these declared mean power loss values for certification.

§1037.570 [Corrected]

2. On page 34488, beginning in the first column, Section 1037.570 is corrected to read as follows:

§1037.570 Procedures to characterize torque converters.

GEM includes input values related to torque converters. This section describes a procedure for mapping a torque converter's capacity factors and torque ratios over a range of operating conditions. You may ask us to approve analytically derived input values based on this testing for additional untested configurations as described in §1037.235(h).

(a) Prepare a torque converter for testing as follows:

(1) Select a torque converter with less than 500 hours of operation before the start of testing.

(2) If the torque converter has a locking feature, unlock it for all testing performed under this section. If the torque converter has a slipping lockup clutch, you may ask us to approve a different strategy based on data showing that it represents better in-use operation.

(3) Mount the torque converter with a transmission to the dynamometer in series or parallel arrangement or mount the torque converter without a transmission to represent a series configuration.

(4) Add transmission oil according to the torque converter manufacturer's instructions, with the following additional specifications:

(i) If the torque converter manufacturer specifies multiple transmission oils, select the one with the highest viscosity at operating temperature. You may use a lower-viscosity transmission oil if we approve that as critical emission-related maintenance under §1037.125.

(ii) Fill the transmission oil to a level that represents in-use operation. If you are testing the torque converter without the transmission, keep output pressure and the flow rate of transmission oil into the torque converter within the torque converter manufacturer's limits.

(iii) You may use an external transmission oil conditioning system, as long as it does not affect measured values.

(5) Install equipment for measuring the bulk temperature of the transmission oil in the oil sump or a similar location and at the torque converter inlet. If the torque converter is tested without a transmission, measure the oil temperature at the torque converter inlet.

(6) Break in the torque converter and transmission (if applicable) using good engineering judgment. Maintain transmission oil temperature at (87 to 93) °C. You may ask us to approve a different range of transmission oil temperatures if you have data showing that it better represents in-use operation.

(b) Measure pump and turbine shaft speed and torque as described in 40 CFR 1065.210(b). You must use a speed measurement system that meets an accuracy of ±0.1 % of point or ±1 r/min, whichever is greater. Use torque transducers that meet an accuracy of ±1.0 % of the torque converter's maximum rated input and output torque, respectively. Calibrate and verify measurement instruments according to 40 CFR part

1065, subpart D. Command speed and torque at a minimum of 10 Hz. Record all speed

and torque data at a minimum of 1 Hz mean values. Note that this section relies on the

convention of describing the input shaft as the pump and the output shaft as the turbine

shaft.

(c) Determine torque converter characteristics based on a test matrix using either constant

input speed or constant input torque as follows:

(1) Constant input speed. Test at constant input speed as follows:

(i) Select a fixed pump speed, f_{npum}, between (1000 and 2000) r/min.

(ii) Test the torque converter at multiple speed ratios, v, in the range of $v = 0.00$ to

$v = 0.95$. Use a step width of 0.10 for the range of $v = 0.00$ to 0.60 and 0.05 for

the range of $v = 0.60$ to 0.95. Calculate speed ratio, v, as turbine shaft speed

divided by pump speed.

(2) Constant input torque. Test at constant input torque as follows:

(i) Set the pump torque, T_{pum}, to a fixed positive value at $f_{npum} = 1000$ r/min with

the torque converter's turbine shaft locked in a non-rotating state (i.e., turbine's

speed, n_{tur}, = 0 r/min).

(ii) Test the torque converter at multiple speed ratios, v, in the range of $v = 0.00$

up to a value of f_{ntur} that covers the usable range of v. Use a step width of 0.10 for

the range of $v = 0.00$ to 0.60 and 0.05 for the range of $v = 0.60$ to 0.95.

(3) You may limit the maximum speed ratio to a value below 0.95 if you have data

showing this better represents in-use operation. You must use the step widths defined

in paragraph (c)(1) or (2) of this section and include the upper limit as a test point. If

you choose a value less than 0.60, you must test at least seven evenly distributed

points between $v = 0$ and your new upper speed ratio.

(d) Characterize the torque converter using the following procedure:

(1) Maintain ambient temperature between (15 and 35) °C throughout testing.

Measure ambient temperature within 1.0 m of the torque converter.

(2) Maintain transmission oil temperature as described in paragraph (a)(6) of this

section. You may use an external transmission oil conditioning system, as long as it

does not affect measured values.

(3) Use good engineering judgment to warm up the torque converter according to the

torque converter manufacturer's specifications.

(4) Test the torque converter at constant input speed or constant input torque as

described in paragraph (c) of this section. Operate the torque converter at $v = 0.00$ for

(5 to 60) seconds, then measure pump torque, turbine shaft torque, angular pump

speed, angular turbine shaft speed, and the transmission oil temperature at the torque

converter inlet for (5 to 15) seconds. Calculate arithmetic mean values for pump

torque, $\overline{T}_{pum}$, turbine shaft torque, $\overline{T}_{tur}$, angular pump speed, $\overline{f}_{npum}$, and angular

turbine shaft speed, $\overline{f}_{ntur}$, over the measurement period. Repeat this stabilization,

measurement, and calculation for the other speed ratios from the test matrix in order

of increasing speed ratio. Adjust the speed ratio by increasing the angular turbine

shaft speed.

(5) Complete a test run by performing the test sequence described in paragraph (d)(4)

of this section two times.

(6) Invalidate the test run if the difference between the pair of mean torque values for the repeat tests at any test point differ by more than ±1 N·m or by more than ±5 % of the average of those two values. This paragraph (d)(6) applies separately for mean pump torque and mean turbine shaft torque at each test point.

(7) Invalidate the test run if any calculated value for mean angular pump speed does not stay within ±5 r/min of the speed setpoint or if any calculated value for mean pump torque does not stay within ±5 N·m of the torque setpoint.

(e) Calculate the mean torque ratio, $\overline{\overline{\mu}}$, at each tested speed ratio, v, as follows:

(1) Calculate $\overline{\mu}$ at each tested speed ratio as follows:

$$\overline{\mu} = \frac{\overline{T}_{tur}}{\overline{T}_{pum}}$$

Eq. 1037.570-1

Where:

$\overline{T}_{tur}$ = mean turbine shaft torque from paragraph (d)(4) of this section.

$\overline{T}_{pum}$ = mean pump torque from paragraph (d)(4) of this section.

(2) Calculate $\overline{\overline{\mu}}$ as the average of the two values of $\overline{\mu}$ at each tested speed ratio.

(3) The following example illustrates a calculation of $\overline{\overline{\mu}}$:

$\overline{T}_{tur,v=0,1} = 332.4$ N·m

$\overline{T}_{pum,v=0,1} = 150.8$ N·m

$\overline{T}_{tur,v=0,2} = 333.6$ N·m

$\overline{T}_{pum,v=0,2} = 150.3$ N·m

$$\bar{\mu}_{v=0,1} = \frac{332.4}{150.8} = 2.20$$

$$\bar{\mu}_{v=0,2} = \frac{333.6}{150.3} = 2.22$$

$$\bar{\bar{\mu}}_{v=0} = \frac{2.20 + 2.22}{2} = 2.21$$

(f) Calculate the mean capacity factor, $\bar{\bar{K}}$, at each tested speed ratio, v, as follows:

(1) Calculate $\bar{K}$ at each tested speed ratio as follows:

$$\bar{K} = \frac{\bar{f}_{npum}}{\sqrt{\bar{T}_{pum}}}$$

Eq. 1037.570-2

Where: $\bar{f}_{npum}$ = mean angular pump speed from paragraph (d)(4) of this section.

$\bar{T}_{pum}$ = mean pump torque from paragraph (d)(4) of this section.

(2) Calculate $\bar{\bar{K}}$ as the average of the two values of $\bar{K}$ at each tested speed ratio.

(3) The following example illustrates a calculation of $\bar{\bar{K}}$:

$$\bar{f}_{npum,v=0,1} = \bar{f}_{npum,v=0,2} = 1000.0 \text{ r/min}$$

$$\bar{T}_{pum,v=0,1} = 150.8 \text{ N·m}$$

$$\bar{K}_{v=0,1} = \frac{1000.0}{\sqrt{150.8}} = 81.43 \text{ r/(min·(N·m)}^{0.5})$$

$$\bar{T}_{pum,v=0,2} = 150.4 \text{ N·m}$$

$$\bar{K}_{v=0,2} = \frac{1000.0}{\sqrt{150.4}} = 81.54 \text{ r/(min·(N·m)}^{0.5})$$

$$\bar{\bar{K}}_{v=0} = \frac{81.43 + 81.54}{2} = 81.49 \ \text{r/(min} \cdot (\text{N} \cdot \text{m})^{0.5})$$

(g) Create a table of GEM inputs showing $\bar{\bar{\mu}}$ and $\bar{\bar{K}}$ at each tested speed ratio, v.

Express $\bar{\bar{\mu}}$ to two decimal places; express $\bar{\bar{K}}$ to one decimal place; express v to two decimal places.

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