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Commission Regulation (EU) 2017/2400 of 12 December 2017 implementing Regulation (EC) No 595/2009 of the European Parliament and of the Council as regards the determination of the CO₂ emissions and fuel consumption of heavy-duty vehicles and amending Directive 2007/46/EC of the European Parliament and of the Council and Commission Regulation (EU) No 582/2011 (Text with EEA relevance)

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ANNEX VI

VERIFYING TRANSMISSION, TORQUE CONVERTER, OTHER TORQUE TRANSFERRING COMPONENT AND ADDITIONAL DRIVELINE COMPONENT DATA

4. Torque converter (TC)

The torque converter characteristics to be determined for the simulation tool input consist of $T_{pum1000}$ (the reference torque at 1 000 rpm input speed) and μ (the torque ratio of the torque converter). Both are depending on the speed ratio ν (= output (turbine) speed / input (pump) speed for the torque converter) of the torque converter.

For determination of the characteristics of the TC, the applicant for a certificate shall apply the following method, irrespective of the chosen option for the assessment of the transmission torque losses.

To take the two possible arrangements of the TC and the mechanical transmission parts into account, the following differentiation between case S and P shall apply:

- Case S : TC and mechanical transmission parts in serial arrangement
Case P : TC and mechanical transmission parts in parallel arrangement (power split installation)

For case S arrangements the TC characteristics may be evaluated either separate from the mechanical transmission or in combination with the mechanical transmission. For case P arrangements the evaluation of TC characteristic is only possible in combination with the mechanical transmission. However, in this case and for the hydromechanical gears subject to measurement the whole arrangement, torque converter and mechanical transmission, is considered as a TC with similar characteristic curves as a sole torque converter.

For the determination of the torque converter characteristics two measurement options may be applied:

- (i) Option A: measurement at constant input speed
(ii) Option B: measurement at constant input torque according to SAE J643

The manufacturer may choose option A or B for case S and case P arrangements.

For the input to the simulation tool, the torque ratio μ and reference torque T_{pum} of the torque converter shall be measured for a range of $\nu \leq 0,95$ (= vehicle propulsion mode). The range of $\nu \geq 1,00$ (= vehicle coasting mode) may either be measured or covered by using the standard values of Table 1.

In case of measurements together with a mechanical transmission the overrun point may be different from $\nu = 1,00$ and therefor the range of measured speed ratios shall be adjusted accordingly.

In case of use of standard values the data on torque converter characteristics provided to the simulation tool shall only cover the range of $\nu \leq 0,95$ (or the adjusted speed ratio). The simulation tool automatically adds the standard values for overrun conditions.

TABLE 1

Default values for $\nu \geq 1,00$

ν	μ	$T_{pum1000}$
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1,000	1,0000	0,00
1,100	0,9999	- 40,34
1,222	0,9998	- 80,34
1,375	0,9997	- 136,11
1,571	0,9996	- 216,52
1,833	0,9995	- 335,19
2,200	0,9994	- 528,77
2,500	0,9993	- 721,00
3,000	0,9992	- 1 122,0
3,500	0,9991	- 1 648,0
4,000	0,9990	- 2 326,0
4,500	0,9989	- 3 182,0
5,000	0,9988	- 4 242,0

4.1. Option A: Measured torque converter characteristics at constant speed

4.1.1. General requirements

The torque converter used for the measurements shall be in accordance with the drawing specifications for series production torque converters.

Modifications to the TC to meet the testing requirements of this Annex, e.g. for the inclusion of measurement sensors are permitted.

Upon request of the approval authority the applicant for a certificate shall specify and prove the conformity with the requirements defined in this Annex.

4.1.2. Oil temperature

The input oil temperature to the TC shall meet the following requirements:

The oil temperature for measurements of the TC separate from the transmission shall be $90\text{ °C} + 7/- 3\text{ K}$.

The oil temperature for measurements of the TC together with the transmission (case S and case P) shall be $90\text{ °C} + 20/- 3\text{ K}$.

The oil temperature shall be measured at the drain plug or in the oil sump.

In case the TC characteristics are measured separately from the transmission, the oil temperature shall be measured prior to entering the converter test drum/bench.

4.1.3. Oil flow rate and pressure

The input TC oil flow rate and output oil pressure of the TC shall be kept within the specified operational limits for the torque converter, depending on the related transmission type and the tested maximum input speed.

4.1.4. Oil quality/Oil viscosity

As specified for transmission testing in 3.1.2.5.3 and 3.1.2.5.4.

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4.1.5. Installation

The torque converter shall be installed on a testbed with a torque sensor, speed sensor and an electric machine installed at the input and output shaft of the TC.

4.1.6. Measurement equipment

The calibration laboratory facilities shall comply with the requirements of either ISO/TS 16949, ISO 9000 series or ISO/IEC 17025. All laboratory reference measurement equipment, used for calibration and/or verification, shall be traceable to national (international) standards.

4.1.6.1. Torque

The torque sensor measurement uncertainty shall be below 1 % of the measured torque value.

The use of torque sensors with higher measurement uncertainties is allowed if the part of the uncertainty exceeding 1 % of the measured torque can be calculated and is added to the measured torque loss as described in 4.1.7.

4.1.6.2. Speed

The uncertainty of the speed sensors shall not exceed ± 1 rpm.

4.1.6.3. Temperature

The uncertainty of the temperature sensors for the measurement of the ambient temperature shall not exceed $\pm 1,5$ K.

The uncertainty of the temperature sensors for the measurement of the oil temperature shall not exceed $\pm 1,5$ K.

4.1.7. Test procedure

4.1.7.1. Zero torque signal compensation

As specified in 3.1.6.1.

4.1.7.2. Measurement sequence

4.1.7.2.1. The input speed n_{pum} of the TC shall be fixed to a constant speed within the range of:

$$1\ 000\ \text{rpm} \leq n_{pum} \leq 2\ 000\ \text{rpm}$$

4.1.7.2.2. The speed ratio ν shall be adjusted by increasing the output speed n_{tur} from 0 rpm up to the set value of n_{pum} .

4.1.7.2.3. The step width shall be 0,1 for the speed ratio range of 0 to 0,6 and 0,05 for the range of 0,6 to 0,95.

4.1.7.2.4. The upper limit of the speed ratio may be limited to a value below 0,95 by the manufacturer. In this case at least seven evenly distributed points between $\nu = 0$ and a value of $\nu < 0,95$ have to be covered by the measurement.

4.1.7.2.5. For each step a minimum of 3 seconds stabilization time within the temperature limits defined in 4.1.2. is required. If needed, the stabilization time may be extended by the manufacturer to maximum 60 seconds. The oil temperature shall be recorded during the stabilization.

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4.1.7.2.6. For each step the signals specified in 4.1.8. shall be recorded for the test point for 3-15 seconds.

4.1.7.2.7. The measurement sequence (4.1.7.2.1. to 4.1.7.2.6.) shall be performed two times in total.

4.1.8. Measurement signals and data recording

At least the following signals shall be recorded during the measurement:

- (1) Input (pump) torque $T_{c,pum}$ [Nm]
- (2) Output (turbine) torque $T_{c,tur}$ [Nm]
- (3) Input rotational (pump) speed n_{pum} [rpm]
- (4) Output rotational (turbine) speed n_{tur} [rpm]
- (5) TC input oil temperature K_{TCin} [°C]

The sampling and recording rate shall be 100 Hz or higher.

A low pass filter shall be applied to avoid measurement errors.

4.1.9. Measurement validation

4.1.9.1. The arithmetic mean values of torque and speed for the 03-15 seconds measurement shall be calculated for each of the two measurements.

4.1.9.2. The measured torques and speeds from the two sets shall be averaged (arithmetic mean values).

4.1.9.3. The deviation between the averaged torque of the two measurement sets shall be below $\pm 5\%$ of the average or ± 1 Nm (whichever value is larger). The arithmetic average of the two averaged torque values shall be taken. If the deviation is higher, the following value shall be taken for point 4.1.10. and 4.1.11. or the test shall be repeated for the TC.

- for the calculation of $\Delta U_{T,pum/tur}$: smallest averaged torque value for $T_{c,pum/tur}$
- for the calculation of torque ratio μ : largest averaged torque value for $T_{c,pum}$
- for the calculation of torque ratio μ : smallest averaged torque value for $T_{c,tur}$
- for the calculation of reference torque $T_{pum1000}$: smallest averaged torque value for $T_{c,pum}$

4.1.9.4. The measured and averaged speed and torque at the input shaft shall be below ± 5 rpm and ± 5 Nm of the speed and torque set point for each measured operating point for the complete speed ratio series.

4.1.10. Measurement uncertainty

The part of the calculated measurement uncertainty $U_{T,pum/tur}$ exceeding 1 % of the measured torque $T_{c,pum/tur}$ shall be used to correct the characteristic value of the TC as defined below.

$$\Delta U_{T,pum/tur} = \text{MAX} (0, (U_{T,pum/tur} - 0,01 * T_{c,pum/tur}))$$

The uncertainty $U_{T,pum/tur}$ of the torque measurement shall be calculated based on the following parameter:

- (i) Calibration error (incl. sensitivity tolerance, linearity, hysteresis and repeatability)

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The uncertainty $U_{T,pum/tur}$ of the torque measurement is based on the uncertainties of the sensors at 95 % confidence level.

$$U_{T,pum/tur} = 2 * u_{cal}$$

$$u_{cal} = 1 \times \frac{W_{cal}}{k_{cal}} \times T_n$$

where:

$T_{c,pum/tur}$	= Current / measured torque value at input/output torque sensor (uncorrected) [Nm]
T_{pum}	= Input (pump) torque (after uncertainty correction) [Nm]
$U_{T,pum/tur}$	= Uncertainty of input / output torque measurement at 95 % confidence level separately for input and output torque sensor [Nm]
T_n	= Nominal torque value of torque sensor [Nm]
u_{cal}	= Uncertainty by torque sensor calibration [Nm]
W_{cal}	= Relative calibration uncertainty (related to nominal torque) [%]
k_{cal}	= Calibration advancement factor (if declared by sensor manufacturer, otherwise = 1)

4.1.11. Calculation of TC characteristics

For each measurement point, the following calculations shall be applied to the measurement data:

The torque ratio of the TC shall be calculated by

$$\mu = \frac{T_{c,tur} - \Delta U_{T,tur}}{T_{c,pum} + \Delta U_{T,pum}}$$

The speed ratio of the TC shall be calculated by

$$v = \frac{n_{tur}}{n_{pum}}$$

The reference torque at 1 000 rpm shall be calculated by

$$T_{pum\ 1000} = (T_{c,pum} - \Delta U_{T,pum}) \times \left(\frac{1000\ rpm}{n_{pum}} \right)^2$$

where:

μ	= Torque ratio of the TC [-]
v	= Speed ratio of the TC [-]
$T_{c,pum}$	= Input (pump) torque (corrected) [Nm]
n_{pum}	= Input rotational (pump) speed [rpm]
n_{tur}	= Output rotational (turbine) speed [rpm]
$T_{pum\ 1000}$	= Reference torque at 1 000 rpm [Nm]

4.2. Option B: Measurement at constant input torque (in accordance with SAE J643)

4.2.1. General requirements

As specified in 4.1.1.

4.2.2. Oil temperature

As specified in 4.1.2.

4.2.3. Oil flow rate and pressure

As specified in 4.1.3.

4.2.4. Oil quality

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As specified in 4.1.4.

4.2.5. Installation

As specified in 4.1.5.

4.2.6. Measurement equipment

As specified in 4.1.6.

4.2.7. Test procedure

4.2.7.1. Zero torque signal compensation

As specified in 3.1.6.1.

4.1.7.2. Measurement sequence

4.2.7.2.1. The input torque T_{pum} shall be set to a positive level at $n_{pum} = 1\ 000$ rpm with the output shaft of the TC held non-rotating (output speed $n_{tur} = 0$ rpm).

4.2.7.2.2. The speed ratio ν shall be adjusted by increasing the output speed n_{tur} from 0 rpm up to a value of n_{tur} covering the usable range of ν with at least seven evenly distributed speed points.

4.2.7.2.3. The step width shall be 0.1 for the speed ratio range of 0 to 0,6 and 0,05 for the range of 0,6 to 0,95.

4.2.7.2.4. The upper limit of the speed ratio may be limited to a value below 0,95 by the manufacturer.

4.2.7.2.5. For each step a minimum of 5 seconds stabilization time within the temperature limits defined in 4.2.2. is required. If needed, the stabilization time may be extended by the manufacturer to maximum 60 seconds. The oil temperature shall be recorded during the stabilization.

4.2.7.2.6. For each step the values specified in 4.2.8. shall be recorded for the test point for 05-15 seconds.

4.2.7.2.7. The measurement sequence (4.2.7.2.1. to 4.2.7.2.6.) shall be performed two times in total.

4.2.8. Measurement signals and data recording

As specified in 4.1.8.

4.2.9. Measurement validation

As specified in 4.1.9.

4.2.10. Measurement uncertainty

As specified in 4.1.9.

4.2.11. Calculation of TC characteristics

As specified in 4.1.11.

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Changes and effects yet to be applied to the whole legislation item and associated provisions

- Signature words omitted by [S.I. 2022/1273 reg. 82\(18\)](#)
- Annex 5 Appendix 6 point 1.3 substituted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(i\)](#)
- Annex 5 Appendix 6 point 1.4.1 image substituted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(iii\)\(aa\)](#)
- Annex 5 Appendix 6 point 1.5.1 image substituted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(iv\)\(aa\)](#)
- Annex 5 Appendix 4 point 7.4 word substituted by [S.I. 2022/1273 reg. 83\(4\)\(a\)](#)
- Annex 5 Appendix 6 point 2.1 word substituted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(v\)](#)
- Annex 5 Appendix 6 point 1.4.1 words omitted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(iii\)\(bb\)](#)
- Annex 5 Appendix 6 point 1.5.1 words omitted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(iv\)\(bb\)](#)
- Annex 5 Appendix 6 point 1.4 words substituted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(ii\)](#)
- Annex 5 Appendix 6 point 2.1 table words substituted by [S.I. 2022/1273 reg. 83\(4\)\(b\)\(vi\)](#)
- Annex 10 Appendix 4 point 1.1 word substituted by [S.I. 2022/1273 reg. 83\(8\)\(d\)\(i\)](#)
- Annex 10 Appendix 1 words substituted by [S.I. 2022/1273 reg. 83\(8\)\(c\)](#)
- Annex 10 Appendix 4 point 1.1 table words substituted by [S.I. 2022/1273 reg. 83\(8\)\(d\)\(ii\)](#)
- Annex 7 Appendix 5 point 1.3 substituted by [S.I. 2022/1273 reg. 83\(6\)\(c\)\(i\)](#)
- Annex 7 Appendix 5 point 1.4.1 image substituted by [S.I. 2022/1273 reg. 83\(6\)\(c\)\(iii\)\(aa\)](#)
- Annex 7 Appendix 1s. 1 point 000.5 word substituted by [S.I. 2022/1273 reg. 83\(6\)\(b\)\(ii\)](#)
- Annex 7 Appendix 1 words inserted by [S.I. 2022/1273 reg. 83\(6\)\(b\)\(i\)\(aa\)](#)
- Annex 7 Appendix 1 words omitted by [S.I. 2022/1273 reg. 83\(6\)\(b\)\(i\)\(bb\)](#)
- Annex 7 Appendix 5 point 1.4.1 words omitted by [S.I. 2022/1273 reg. 83\(6\)\(c\)\(iii\)\(bb\)](#)
- Annex 7 Appendix 5 point 1.4 words substituted by [S.I. 2022/1273 reg. 83\(6\)\(c\)\(ii\)](#)
- Annex 7 Appendix 5 point 2.1 words substituted by [S.I. 2022/1273 reg. 83\(6\)\(c\)\(iv\)](#)
- Annex 7 Appendix 5 point 2.1 table words substituted by [S.I. 2022/1273 reg. 83\(6\)\(c\)\(v\)](#)
- Annex 8 Appendix 8 point 1.3 substituted by [S.I. 2022/1273 reg. 83\(7\)\(d\)\(i\)](#)
- Annex 8 Appendix 8 point 1.4.1 image substituted by [S.I. 2022/1273 reg. 83\(7\)\(d\)\(iii\)\(aa\)](#)
- Annex 8 Appendix 4 table 11 word omitted by [S.I. 2022/1273 reg. 83\(7\)\(c\)\(i\)](#)
- Annex 8 Appendix 4 table 13 word omitted by [S.I. 2022/1273 reg. 83\(7\)\(c\)\(i\)](#)
- Annex 8 Appendix 4 table 15 word omitted by [S.I. 2022/1273 reg. 83\(7\)\(c\)\(ii\)\(aa\)](#)
- Annex 8 Appendix 4 table 15 word omitted by [S.I. 2022/1273 reg. 83\(7\)\(c\)\(ii\)\(bb\)](#)
- Annex 8 Appendix 1s. 1 point 000.6 word substituted by [S.I. 2022/1273 reg. 83\(7\)\(b\)\(ii\)](#)
- Annex 8 Appendix 8 point 2.1 word substituted by [S.I. 2022/1273 reg. 83\(7\)\(d\)\(iv\)](#)
- Annex 8 Appendix 1 words inserted by [S.I. 2022/1273 reg. 83\(7\)\(b\)\(i\)\(aa\)](#)
- Annex 8 Appendix 1 words omitted by [S.I. 2022/1273 reg. 83\(7\)\(b\)\(i\)\(bb\)](#)
- Annex 8 Appendix 8 point 1.4.1 words omitted by [S.I. 2022/1273 reg. 83\(7\)\(d\)\(iii\)\(bb\)](#)
- Annex 8 Appendix 8 point 1.4 words substituted by [S.I. 2022/1273 reg. 83\(7\)\(d\)\(ii\)](#)
- Annex 8 Appendix 8 point 2.1 table words substituted by [S.I. 2022/1273 reg. 83\(7\)\(d\)\(v\)](#)

- Annex 2 Appendix 2s. 2 point 2 omitted by S.I. 2022/1273 reg. 83(2)(b)(ii)
- Annex 2 Appendix 2 words inserted by S.I. 2022/1273 reg. 83(2)(b)(i)
- Annex 6 Appendix 7 point 1.3 substituted by S.I. 2022/1273 reg. 83(5)(e)(i)
- Annex 6 Appendix 7 point 1.5 image substituted by S.I. 2022/1273 reg. 83(5)(e)(iii)(aa)
- Annex 6 Appendix 7 point 2.1 word substituted by S.I. 2022/1273 reg. 83(5)(e)(iv)
- Annex 6 Appendix 1 words omitted by S.I. 2022/1273 reg. 83(5)(c)
- Annex 6 Appendix 7 point 1.5 words omitted by S.I. 2022/1273 reg. 83(5)(e)(iii)(bb)
- Annex 6 Appendix 2 point 8 words substituted by S.I. 2022/1273 reg. 83(5)(d)
- Annex 6 Appendix 3 point 8 words substituted by S.I. 2022/1273 reg. 83(5)(d)
- Annex 6 Appendix 4 point 8 words substituted by S.I. 2022/1273 reg. 83(5)(d)
- Annex 6 Appendix 5 point 8 words substituted by S.I. 2022/1273 reg. 83(5)(d)
- Annex 6 Appendix 7 point 1.4 words substituted by S.I. 2022/1273 reg. 83(5)(e)(ii)
- Annex 6 Appendix 7 point 2.1 table words substituted by S.I. 2022/1273 reg. 83(5)(e)(v)
- Art. 3(5) omitted by S.I. 2022/1273 reg. 82(4)(a)
- Art. 3(16) words substituted by S.I. 2022/1273 reg. 82(4)(b)
- Art. 3(20) words substituted by S.I. 2022/1273 reg. 82(4)(c)
- Art. 10(1a) inserted by S.I. 2022/1273 reg. 82(8)(b)
- Annex 10a para. 3(f) words inserted by S.I. 2022/1273 reg. 83(9)(a)
- Annex 10a para. 3(f) table words substituted by S.I. 2022/1273 reg. 83(9)(b)(c)
- Art. 12(8) inserted by S.I. 2022/1273 reg. 82(10)