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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 CO_2 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)

(OJ L 349, 29.12.2017, p. 1)

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(Text with EEA relevance)

CHAPTER 1

GENERAL PROVISIONS

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Article 1

Subject matter

This Regulation complements the legal framework for the type-approval of motor vehicles and engines with regard to emissions established by Regulation (EU) No 582/2011 by laying down the rules for issuing licences to operate a simulation tool with a view to determining CO_2 emissions and fuel consumption of new vehicles to be sold, registered or put into service in the Union and for operating that simulation tool and declaring the CO_2 emissions and fuel consumption values thus determined.

Article 2

Scope

1. Subject to Article 4, second paragraph, this Regulation shall apply to medium lorries, heavy lorries and heavy buses.

2. In the case of multi-stage type-approvals or individual approvals of medium and heavy lorries, this Regulation shall apply to base lorries.

In the case of heavy buses, this Regulation shall apply to primary vehicles, interim vehicles and to complete vehicles or completed vehicles.

3. This Regulation shall not apply to off-road vehicles, special purpose vehicles and off-road special purpose vehicles as defined, respectively, in Part A, points 2.1., 2.2. and 2.3., of Annex I to Regulation (EU) 2018/858 of the European Parliament and of the Council (1).

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Article 3

Definitions

For the purposes of this Regulation, the following definitions shall apply:

(1) Regulation (EU) 2018/858 of the European Parliament and of the Council of 30 May 2018 on the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, amending Regulations (EC) No 715/2007 and (EC) No 595/2009 and repealing Directive 2007/46/EC (OJ L 151, 14.6.2018, p. 1).

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(1) ‘CO_2 emissions and fuel consumption related properties’ means specific properties derived for a component, separate technical unit and system which determine the impact of the part on the CO_2 emissions and fuel consumption of a vehicle;

(2) ‘input data’ means information on the CO_2 emissions and fuel consumption related properties of a component, separate technical unit or system which is used by the simulation tool for the purpose of determining CO_2 emissions and fuel consumption of a vehicle;

(3) ‘input information’ means information relating to the characteristics of a vehicle which is used by the simulation tool for the purposes of determining their CO_2 emissions and fuel consumption of the vehicle and which is not part of an input data;

(4) ‘manufacturer’ means the person or body who is responsible to the approval authority for all aspects of the certification process and for ensuring conformity of CO_2 emissions and fuel consumption related properties of components, separate technical units and systems. It is not essential that the person or body be directly involved in all stages of the construction of the component, separate technical unit or system which is the subject of the certification.

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(4a) ‘vehicle manufacturer’ means a body or person responsible for issuing the manufacturer's records file and the customer information file pursuant to Article 9;

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(5) ‘authorised entity’ means a national authority authorised by a Member State to request relevant information from the manufacturers and vehicle manufacturers on the CO_2 emissions and fuel consumption related properties of a specific component, specific separate technical unit or specific system and CO_2 emissions and fuel consumption of new vehicles respectively.

(6) ‘transmission’ means a device consisting of at least of two shiftable gears, changing torque and speed with defined ratios;

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(7) ‘torque converter’ means a hydrodynamic start-up component either as a separate component of the driveline or transmission with serial or parallel power flow that adapts speed between engine and wheel and provides torque multiplication;

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(8) ‘other torque transferring component’ or ‘OTTC’ means a rotating component attached to the driveline which produces torque losses dependent on its own rotational speed;

(9) ‘additional driveline component’ or ‘ADC’ means a rotating component of the driveline which transfers or distributes power to other driveline components and produces torque losses dependant on its own rotational speed;

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(10) ‘axle’ means a component comprising all rotating parts of the driveline which transfer the driving torque coming from the prop shaft to the wheels and changes the torque and speed with a fixed ratio and including the functions of a differential gear;

(11) ‘air drag’ means characteristic of a vehicle configuration regarding aerodynamic force acting on the vehicle in the direction of air flow and determined as a product of the drag coefficient and the cross sectional area for zero crosswind conditions;

(12) ‘auxiliaries’ means vehicle components including an engine fan, steering system, electric system, pneumatic system and Heating, Ventilation and Air Conditioning (HVAC) system whose CO_2 emissions and fuel consumption properties have been defined in Annex IX;

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(13) ‘component family’, ‘separate technical unit family’ or ‘system family’ means a manufacturer's grouping of components, separate technical units or systems, respectively, which through their design have similar CO_2 emissions and fuel consumption related properties;

(14) ‘parent component’, ‘parent separate technical unit’ or ‘parent system’ means a component, separate technical unit or system, respectively, selected from a component, separate technical unit or system family, respectively, in such a way that its CO_2 emissions and fuel consumption related properties will be the worst case for that component family, separate technical unit family or system family;

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(15) ‘zero emission heavy-duty vehicle’ (Ze-HDV) means ‘zero emission heavy-duty vehicle’ as defined in Article 3, point (11), of Regulation (EU) 2019/1242 of the European Parliament and of the Council;

(16) ‘vocational vehicle’ means a heavy-duty vehicle not intended for the delivery of goods and for which one of the following digits is used to supplement the bodywork codes, as listed in Appendix 2 to Annex I to Regulation (EU) 2018/858: 09, 10, 15, 16, 18, 19, 20, 23, 24, 25, 26, 27, 28, 31; or a tractor with a maximum speed not exceeding 79 km/h;

(17) ‘rigid lorry’ means a ‘lorry’ as defined in Part C, point 4.1, of Annex I to Regulation (EU) 2018/858, except for the lorries designed or constructed for the towing of a semi-trailer;

(18) ‘tractor’ means a ‘tractor unit for semi-trailer’ as defined in Part C, point 4.3, of Annex I to Regulation (EU) 2018/858

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(19) ‘sleeper cab’ means a type of cabin that has a compartment behind the driver's seat intended to be used for sleeping;

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(20) ‘hybrid electric heavy-duty vehicle’ (He-HDV) means a hybrid heavy duty vehicle that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy or power: (i) a consumable fuel, and (ii) an electrical energy or power storage device;

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(21) ‘dual-fuel vehicle’ is as defined in Article 2(48) of Regulation (EU) No 582/2011;

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(22) ‘primary vehicle’ means a heavy bus in a virtual assembly condition determined for simulation purposes, for which the input data and input information as set out in Annex III is used;

(23) ‘manufacturer’s records file’ means a file produced by the simulation tool which contains manufacturer related information, a documentation of the input data and input information to the simulation tool and the results for CO_2 emissions and fuel consumption;

(24) ‘customer information file’ means a file produced by the simulation tool which contains a defined set of vehicle related information and the results for CO_2 emissions and fuel consumption as defined in Part II of Annex IV;

(25) ‘vehicle information file’ (VIF) means a file produced by the simulation tool for heavy buses to transfer the relevant input data, input information and simulation results to subsequent manufacturing stages following the method as described in point (2) of Annex I;

(26) ‘medium lorry’ means a vehicle of category N_2, as defined in Article 4(1), point (b)(ii), of Regulation (EU) 2018/858, with a technically permissible maximum laden mass exceeding 5 000 kg and not exceeding 7 400 kg;

(27) ‘heavy lorry’ means a vehicle of category N_2, as defined in Article 4(1), point (b)(ii), of Regulation (EU) 2018/858, with a technically permissible maximum laden mass exceeding 7 400 kg and a vehicle of category N_3, as defined in Article 4(1), point (b)(iii), of that Regulation;

(28) ‘heavy bus’ means a vehicle of category M_3, as defined in Article 4(1), point (a)(iii), of Regulation (EU) 2018/858, with a technically permissible maximum laden mass of more than 7 500 kg;

(29) ‘primary vehicle manufacturer’ means a manufacturer responsible for the primary vehicle;

(30) ‘interim vehicle’ means any further completion of a primary vehicle where a sub-set of input data and input information as defined for the complete or completed vehicle in accordance with Table 1 and Table 3a of Annex III is added and/or modified;

(31) ‘interim manufacturer’ means a manufacturer responsible for an interim vehicle;

(32) ‘incomplete vehicle’ means ‘incomplete vehicle’ as defined in Article 3, point (25), of Regulation (EU) 2018/858;

(33) ‘completed vehicle’ means ‘completed vehicle’ as defined in Article 3, point (26), of Regulation (EU) 2018/858;

(34) ‘complete vehicle’ means ‘complete vehicle’ as defined in Article 3, point (27), of Regulation (EU) 2018/858;

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(35) ‘standard value’ is input data for the simulation tool for a component where certification of input data is applicable, but the component has not been tested to determine a specific value and which reflects the worst-case performance of a component;

(36) ‘generic value’ is data used in the simulation tool for components or vehicle parameters where no component testing or declaration of specific values is foreseen and which reflects performance of average component technology or typical vehicle specifications;

(37) ‘van’ means a ‘van’ as defined in Part C, point 4.2, of Annex I to Regulation (EU) 2018/858;

(38) ‘application case’ means the different scenarios to be followed in the case of a medium lorry, heavy lorry, heavy bus that is a primary vehicle, heavy bus that is an interim vehicle, heavy bus that is a complete vehicle or completed vehicle for which different manufacturer provisions and functions are applicable in the simulation tool;

(39) ‘base lorry’ means a medium lorry or heavy lorry equipped at least with:

— a chassis, engine, transmission, axles and tyres, in the case of pure internal combustion engine vehicles;

— a chassis, electric machine system and/or integrated electric powertrain component, battery system(s) and/or capacitor system(s) and tyres, in the case of pure electric vehicles;

— a chassis, engine, electric machine system and/or integrated electric powertrain component and/or integrated hybrid electric vehicle powertrain component type 1, battery system(s) and/or capacitor system(s) and tyres, in the case of hybrid electric heavy-duty vehicles.

Article 4

Vehicle groups

For the purpose of this Regulation, motor vehicles shall be classified in vehicle groups in accordance with Annex I, Tables 1 to 6.

Articles 5 to 23 do not apply to heavy lorries of vehicle groups 6, 7, 8, 13, 14, 15, 17, 18 and 19 as set out in Table 1 of Annex I, and to medium lorries of vehicle groups 51, 52, 55 and 56, as set out in Table 2 of Annex I and to any vehicle with a driven front axle in the vehicle groups 11, 12 and 16 as set out in Table 1 of Annex I.

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Article 5

Electronic tools

1. The Commission shall provide free of charge the following electronic tools in the form of downloadable and executable software:

(a) a simulation tool;

(b) pre-processing tools;

(c) a hashing tool.

The Commission shall maintain the electronic tools and provide modifications and updates to those tools.

2. The Commission shall make the electronic tools referred to in paragraph 1 available through a publicly available dedicated electronic distribution platform.

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3. ►M3 The simulation tool shall be used for the purposes of determining CO_2 emissions and fuel consumption of new vehicles. ◄ The simulation tool shall be designed to operate on the basis of input information as specified in Annex III, as well as input data referred to in Article 12(1).

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4. The pre-processing tools shall be used for the purpose of verification and compilation of the testing results and performing additional calculations relating to CO_2 emission and fuel consumption related properties of certain components, separate technical units or systems and converting them in a format used by the simulation tool. The pre-processing tools shall be used by the manufacturer after performing the tests referred to in point 4 of Annex V for engines and in point 3 of Annex VIII for air-drag.

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5. The hashing tools shall be used for establishing an unequivocal association between the certified CO_2 emission and fuel consumption related properties of a component, separate technical unit or system and its certification document, as well as for establishing an unequivocal association between a vehicle and its manufacturer's records file, vehicle information file and customer information file as referred to in Annex IV.

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CHAPTER 2

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LICENCE TO OPERATE THE SIMULATION TOOL FOR THE PURPOSES OF TYPE-APPROVAL WITH REGARD TO EMISSIONS

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Article 6

Application for a licence to operate the simulation tool with a view to determining CO_2 emissions and fuel consumption of new vehicles

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1. The vehicle manufacturer shall submit to the approval authority an application for a licence to operate the simulation tool for an application case with a view to determining CO_2 emissions and fuel consumption of

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new vehicles belonging to one or more vehicle groups ('licence'). An individual licence shall apply to only a single such application case.

The application for a licence shall be accompanied by an adequate description of the processes set up by the vehicle manufacturer with a view to the operation of the simulation tool with respect to the application case concerned, as set out in point (1) of Annex II.

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2. The application for a licence shall take the form of an information document drawn up in accordance with the model set out in Appendix 1 to Annex II.

3. The application for a licence shall be accompanied by an adequate description of the processes set up by the manufacturer for the purposes of determining CO_2 emissions and fuel consumption with respect to all the vehicle groups concerned, as set out in point 1 of Annex II.

It shall also be accompanied by the assessment report drafted by the approval authority after performing an assessment in accordance with point 2 of Annex II.

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4. The vehicle manufacturer shall submit the application for a licence to the approval authority at the latest together with the application for an EC type-approval of a vehicle with an approved engine system with regard to emissions pursuant to Article 7 of Regulation (EU) No 582/2011, with the application for an EC type-approval of a vehicle with regard to emissions pursuant to Article 9 of that Regulation, with an application for a whole-vehicle type-approval pursuant to Regulation (EU) 2018/858 or the application for a national individual vehicle approval. The approval of a pure electric engine system and the EC type-approval of a pure electric vehicle with regard to emissions referred to in the previous sentence is limited to the measurement of net engine power in accordance with Annex XIV to Regulation (EU) No 582/2011.

The application for a licence must concern the application case which includes the type of vehicle concerned by the application for EU type-approval.

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Article 7

Administrative provisions for the granting of the licence

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1. The approval authority shall grant the licence if the vehicle manufacturer submits an application in accordance with Article 6 and proves that the requirements laid down in Annex II are met with respect to the application case concerned.

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2. The licence shall be issued in accordance with the model set out in Appendix 2 to Annex II.

Article 8

Subsequent changes to the processes set up for the purposes of determining CO_2 emissions and fuel consumption of vehicles

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2. The vehicle manufacturer shall apply for an extension of the licence in accordance with Article 6 (1), (2) and (3).

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3. After obtaining the licence, the vehicle manufacturer shall notify the approval authority without delay of any changes to the processes set up by it for the purposes of the licence for the application case covered by the licence that may affect the accuracy, reliability and stability of those processes.

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4. Upon receipt of the notification referred to in paragraph 3, the approval authority shall inform the vehicle manufacturer whether processes affected by the changes continue to be covered by the licence granted, whether the licence must be extended in accordance with paragraphs 1 and 2 or whether a new licence should be applied for in accordance with Article 6.

5. Where the changes are not covered by the licence, the manufacturer shall, within one month of receipt of the information referred to in paragraph 4, apply for an extension of the licence or for a new licence. If the manufacturer does not apply for an extension of the licence or a new licence within that deadline, or if the application is rejected, the licence shall be withdrawn.

CHAPTER 3

OPERATION OF THE SIMULATION TOOL WITH A VIEW TO DETERMINING THE CO_2 EMISSIONS AND FUEL CONSUMPTION FOR THE PURPOSES OF REGISTRATION, SALE AND ENTRY INTO SERVICE OF NEW VEHICLES

Article 9

Obligation to determine and declare CO_2 emissions and fuel consumption of new vehicles

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1. A vehicle manufacturer shall determine the CO_2 emissions and fuel consumption of each new vehicle, with the exception of new vehicles using vehicle technologies listed in Appendix 1 to Annex III, to be sold, registered or put into service in the Union using the latest available version of the simulation tool referred to in Article 5(3). With regard to heavy buses the vehicle manufacturer or interim manufacturer shall use the method set out in Annex I, point (2).

For vehicle technologies listed in Appendix 1 to Annex III to be sold, registered or put into service in the Union, the vehicle manufacturer or interim manufacturer shall determine only the input parameters specified for those vehicles in the models set out in Table 5 of Annex III, using the latest available version of the simulation tool referred to in Article 5(3).

A vehicle manufacturer may operate the simulation tool for the purposes of this Article only if in possession of a licence granted for the application case concerned in accordance with Article 7. An interim manufacturer operates the simulation tool under the licence of a vehicle manufacturer.

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2. The vehicle manufacturer shall record the results of the simulation performed in accordance with the first subparagraph of paragraph 1 in the manufacturer's records file drawn up in accordance with the model set out in Part I of Annex IV.

With the exception of the cases referred to in the second subparagraph of Article 21(3), and in Article 23(6), any subsequent changes to the manufacturer's records file shall be prohibited.

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Vehicle manufacturers of heavy buses additionally shall record the results of the simulation in the vehicle information file. Interim manufacturers of heavy buses shall record the vehicle information file.

3. The vehicle manufacturer of medium lorries and heavy lorries shall create cryptographic hashes of the manufacturer’s records file and of the customer information file.

The primary vehicle manufacturer shall create cryptographic hashes of the manufacturer’s records file and of the vehicle information file.

The interim manufacturer shall create the cryptographic hash of the vehicle information file.

The vehicle manufacturer of complete vehicles or completed vehicles that are heavy buses, shall create cryptographic hashes of the manufacturer’s records file, of the customer information file and of the vehicle information file.

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4. ►M3 Lorries and complete vehicles or completed vehicles that are heavy buses to be registered, sold or to enter into service shall be accompanied by the customer information file drawn up by the manufacturer in accordance with the model set out in Part II of Annex IV. ◄

Each customer information file shall include an imprint of the cryptographic hash of the manufacturer's records file referred to in paragraph 3.

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Vehicle manufacturers of heavy buses shall make the vehicle information file available to the manufacturer of a subsequent step in the chain.

5. For each vehicle accompanied by a certificate of conformity or, in the case of vehicles approved in accordance with Article 45 of Regulation (EU) 2018/858, an individual vehicle approval certificate, the certificate shall include an imprint of the cryptographic hashes referred to in paragraph 3 of this Article.

6. In accordance with point 11 of Annex III, a manufacturer may transfer results of the simulation tool to other vehicles.

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Article 10

Modifications, updates and malfunction of the electronic tools

1. In the case of modifications or updates to the simulation tool, the vehicle manufacturer shall start using the modified or updated simulation tool no later than 3 months after the modifications and updates were made available on the dedicated electronic distribution platform.

2. If the CO_2 emissions and fuel consumption of new vehicles cannot be determined in accordance with Article 9(1) due to a malfunction of the simulation tool, the vehicle manufacturer shall notify the Commission thereof without delay by means of the dedicated electronic distribution platform.

3. If the CO_2 emissions and fuel consumption of new vehicles cannot be determined in accordance with Article 9(1) due to a malfunction of the simulation tool, the vehicle manufacturer shall perform the simulation of those vehicles not later than 7 calendar days after the date referred to in point 1. Until then, the obligations resulting from Article 9 for the vehicles for which the determination of fuel consumption and CO_2 emissions remains impossible shall be suspended.

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Where a malfunction of the simulation tool occurs at a step in the manufacturing chain of heavy buses prior to the complete or completed manufacturing steps, the obligation under Article 9(1) to operate the simulation tool at the subsequent manufacturing steps shall be postponed for a maximum of 14 calendar days after the date on which the manufacturer at the previous step made the vehicle information file available to the manufacturer of the complete or completed step.

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Article 11

Accessibility of the simulation tool inputs and output information

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1. The manufacturer's records file, the vehicle information file and the certificates on CO_2 emissions and fuel consumption related properties of the components, systems and separate technical units shall be stored by the vehicle manufacturer for at least 20 years after the production of the vehicle and shall be available, upon request, to the approval authority and to the Commission.

2. Upon request by an authorised entity of a Member State or by the Commission, the vehicle manufacturer shall provide, within 15 working days, the manufacturer's records file or the vehicle information file.

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3. Upon request by an authorised entity of a Member State or by the Commission, the approval authority which granted the licence in accordance with Article 7 or certified the CO_2 emissions and fuel consumption related properties of a component, separate technical unit or system in accordance with Article 17 shall provide, within 15 working days, the information document referred to in Article 6(2) or in Article 16(2), respectively.

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CHAPTER 4

CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF COMPONENTS, SEPARATE TECHNICAL UNITS AND SYSTEMS

Article 12

Components, separate technical units and systems relevant for the purposes of determining CO_2 emissions and fuel consumption

1. The simulation tool input data referred to in Article 5(3) shall include information relating to the CO_2 emissions and fuel consumption related properties of the following components, separate technical units and systems:

(a) engines;

(b) transmissions;

(c) torque converters;

(d) other torque transferring components;

(e) additional driveline components;

(f) axles;

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(g) air drag;

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(h) auxiliaries;

(i) tyres;

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(j) electric powertrain components.

2. The CO_2 emissions and fuel consumption related properties of the components, separate technical units and systems referred to in points (b) to (g), (i) and (j) of paragraph 1 of this Article shall be based either on the values determined, for each component, separate technical unit, system or if applicable their respective family, in accordance with Article 14 and certified in accordance with Article 17 ('certified values') or, in the absence of the certified values, on the standard values determined in accordance with Article 13.

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3. The CO_2 emissions and fuel consumption related properties of engines shall be based on the values determined for each engine family in accordance with Article 14 and certified in accordance with Article 17.

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4. The CO_2 emissions and fuel consumption related properties of auxiliaries shall be based on the generic values as implemented in the simulation tool and as allocated to a vehicle based on the input information to be determined in accordance with Annex IX.

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5. In the case of a base lorry, the CO_2 emissions and fuel consumption related properties of components, separate technical units and systems referred to in paragraph 1, point (g), of this Article, which cannot be determined for the base lorries shall be based on the standard values. For components, separate technical units and systems referred to in paragraph 1, point (h), the technology with highest power losses shall be selected by the vehicle manufacturer.

6. In the case of vehicles exempted from the obligation to determine the CO_2 emissions and fuel consumption under Article 9(1), the simulation tool input data shall include the information set out in Table 5 of Annex III.

7. Where the vehicle is to be registered, sold or put into service with a complete set of snow tyres and a complete set of standard tyres, the vehicle manufacturer may choose which of the tyres to use for determining the CO_2 emissions. In the case of heavy buses, as long as the tyres used in the primary vehicle simulation are with the vehicle when it is registered, sold or put into service, addition of tyre sets to the vehicle shall not result in the obligation to conduct a new primary vehicle simulation in accordance with point 2 of Annex I.

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Article 13

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Standard values and generic values

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1. The standard values for transmissions shall be determined in accordance with Appendix 8 of Annex VI.

2. The standard values for torque converters shall be determined in accordance with Appendix 9 of Annex VI.

3. The standard values for other torque-transferring components shall be determined in accordance with Appendix 10 of Annex VI.

4. The standard values for additional driveline components shall be determined in accordance with Appendix 11 of Annex VI.

5. The standard values for axles shall be determined in accordance with Appendix 3 of Annex VII.

6. The standard values for a body or trailer air drag shall be determined in accordance with Appendix 7 of Annex VIII.

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7. For auxiliaries generic values are allocated by the simulation tool in accordance with the technologies selected in accordance with Annex IX.

8. The standard value for tyres shall be determined in accordance with Annex X, point 3.2.

9. The standard values for electric powertrain components shall be determined in accordance with Appendices 8, 9 and 10 to Annex Xb.

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Article 14

Certified values

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1. The values determined in accordance with paragraphs 2 to 10 of this Article may be used by the vehicle manufacturer as the simulation tool input data if they are certified in accordance with Article 17.

2. The certified values for engines shall be determined in accordance with points 4, 5 and 6 of Annex V.

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3. The certified values for transmissions shall be determined in accordance with point 3 of Annex VI.

4. The certified values for torque converters shall be determined in accordance with point 4 of Annex VI.

5. The certified values for other torque-transferring component shall be determined in accordance with point 5 of Annex VI.

6. The certified values for additional driveline components shall be determined in accordance with point 6 of Annex VI.

7. The certified values for axles shall be determined in accordance with point 4 of Annex VII.

8. The certified values for a body or trailer air drag shall be determined in accordance with point 3 of Annex VIII.

9. The certified values for tyres shall be determined in accordance with Annex X.

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10. The certified values for electric powertrain components shall be determined in accordance with points 4, 5 and 6 of Annex Xb.

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Article 15

Family concept regarding components, separate technical units and systems using certified values

1. Subject to paragraphs 3 to 6, the certified values determined for a parent component, parent separate technical unit or parent system shall be valid, without further testing, for all family members in accordance with the family definition as set out in:

— Appendix 6 to Annex VI as regards the family concept of transmissions, torque converters, other torque transferring component and additional driveline components;

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— Appendix 4 to Annex VII as regards the family concept of axles;

— Appendix 5 to Annex VIII as regards the family concept for the purposes of determining air drag;

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— Appendix 3 to Annex V as regards engines, the certified values for the members of an engine family created in accordance with the family definition shall be derived in accordance with points 4, 5 and 6 of Annex V;

— Appendix 13 to Annex Xb as regards the family concept of electric machine systems or integrated electric powertrain components, the certified values for the members of a family created in accordance with the family definition of electric machine systems, shall be derived in accordance with point 4 of Annex Xb.

2. For engines, the certified values for the members of an engine family shall be derived in accordance with points 4, 5 and 6 of Annex V.

For tyres, a family shall consist of one tyre type only.

For electric machine systems or integrated electric powertrain components, the certified values for the members of a family of electric machine systems shall be derived in accordance with point 4 of Annex Xb.

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3. The CO_2 emissions and fuel consumption related properties of the parent component, parent separate technical unit or parent system shall not be better than the properties of any member of the same family.

4. The manufacturer shall provide the approval authority with evidence that the parent component, separate technical units or system fully represents the component family, separate technical unit family or system family.

If, in the framework of testing for the purposes of the second subparagraph of Article 16(3), the approval authority determines that the selected parent component, parent separate technical unit or parent system does not fully represent the component family, separate technical unit family or system family, an alternative reference component, separate technical units or system may be selected by the approval authority, tested and shall become a parent component, parent separate technical unit or parent system.

5. Upon request of the manufacturer, and subject to the agreement by the approval authority, the CO_2 emissions and fuel consumption related properties of a specific component, specific separate technical unit or specific system other than a parent component, parent separate technical unit or parent system, respectively, may be indicated in the certificate on CO_2 emissions and fuel consumption related properties of the component family, separate technical unit family or system family.

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The CO_2 emissions and fuel consumption related properties of that specific component, separate technical unit or system shall be determined in accordance with Article 14.

6. Where the characteristics of the specific component, specific separate technical unit or specific system, in terms of CO_2 emissions and fuel consumption related properties as determined in accordance with paragraph 5, lead to higher CO_2 emissions and fuel consumption values than those of the parent component, parent separate technical unit or parent system, respectively, the manufacturer shall exclude it from the existing family, assign it to a new family and define it as the new parent component, parent separate technical unit or parent system for that family or apply for an extension of the certification pursuant to Article 18.

Article 16

Application for a certification of the CO_2 emissions and fuel consumption related properties of components, separate technical units or systems

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1. The application for certification of the CO_2 emissions and fuel consumption related properties of the component, separate technical unit and systems, or if applicable their respective families, shall be submitted to the approval authority.

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2. The application for certification shall take the form of an information document drawn up in accordance with the model set out in:

— Appendix 2 to Annex V as regards engines;

— Appendix 2 to Annex VI as regards transmissions;

— Appendix 3 to Annex VI as regards torque converters;

— Appendix 4 to Annex VI as regards other torque transferring component;

— Appendix 5 to Annex VI as regards additional driveline components;

— Appendix 2 to Annex VII as regards axles;

— Appendix 2 to Annex VIII as regards air drag;

— Appendix 2 to Annex X as regards tyres;

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— Appendixes 2 to 6 to Annex Xb as regards electric powertrain components.

3. The application for certification shall be accompanied by an explanation of the elements of design of the component, separate technical unit and system, or if applicable their respective families concerned which have a non-negligible effect on the CO_2 emissions and fuel consumption related properties of the components, separate technical units or systems concerned.

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The application shall also be accompanied by the relevant test reports issued by an approval authority, test results, and by a statement of compliance issued by an approval authority pursuant to point 2 of Annex IV to Regulation (EU) 2018/858.

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Article 17

Administrative provisions for the certification of CO_2 emissions and fuel consumption related properties of components, separate technical units and systems

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1. If all the applicable requirements are met, the approval authority shall certify the values relating to the CO_2 emissions and fuel consumption related properties of the component, separate technical unit and system, or if applicable their respective families concerned.

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2. In the case referred to in paragraph 1, the approval authority shall issue a certificate on CO_2 emissions and fuel consumption related properties using the model set out in:

— Appendix 1 to Annex V as regards engines;

— Appendix 1 to Annex VI as regards transmissions, torque converters, other torque transferring component and additional driveline components;

— Appendix 1 to Annex VII as regards axles;

— Appendix 1 to Annex VIII as regards air drag;

— Appendix 1 to Annex X as regards tyres;

▼M3

— Appendix 1 to Annex Xb as regards electric powertrain components.

▼B

3. The approval authority shall grant a certification number in accordance with the numbering system set out in:

— Appendix 6 to Annex V as regards engines;

— Appendix 7 to Annex VI as regards transmissions, torque converters, other torque transferring component and additional driveline components;

— Appendix 5 to Annex VII as regards axles;

— Appendix 8 to Annex VIII as regards air drag;

— Appendix 1 to Annex X as regards tyres;

▼M3

— Appendix 14 to Annex Xb as regards electric powertrain components.

The approval authority shall not assign the same number to another component, separate technical unit and system, or if applicable their respective families. The certification number shall be used as the identifier of the test report.

▼B

4. The approval authority shall create a cryptographic hash of the file with test results, comprising the certification number, by means of the hashing tool referred to in Article 5(5). This hashing shall be done immediately after the test results are produced. The approval authority shall imprint that hash along with the certification number on the certificate on CO_2 emissions and fuel consumption related properties.

Article 18

Extension to include a new component, separate technical unit or system into a component family, separate technical unit family or system family

1. At the request of the manufacturer and upon approval of the approval authority, a new component, separate technical unit or system may be included as a member of a certified component family, separate technical unit family or system family if they meet the criteria for family definition set out in:

▼M3

— Appendix 3 to Annex V as regards the family concept of engines, taking into account the requirements of Article 15(2);

▼B

— Appendix 6 to Annex VI as regards the family concept of transmissions, torque converters, other torque transferring component and additional driveline components;

— Appendix 4 to Annex VII as regards the family concept of axles;

— Appendix 5 to Annex VIII as regards the family concept for the purposes of determining air drag;

▼M3

— Appendix 13 to Annex Xb as regards the family concept of electric machine systems or integrated electric powertrain components, taking into account the requirements of Article 15(2).

▼B

In such cases, the approval authority shall issue a revised certificate denoted by an extension number.

The manufacturer shall modify the information document referred to in Article 16(2) and provide it to the approval authority.

2. Where the characteristics of the specific component, specific separate technical unit or specific system, in terms of CO_2 emissions and fuel consumption related properties as determined in accordance with paragraph 1, lead to higher CO_2 emissions and fuel consumption values than those of the parent component, parent separate technical unit or parent system, respectively, the new component, separate technical unit or system shall become the new parent component, separate technical unit or system.

▼B

Article 19

Subsequent changes relevant for the certification of CO_2 emissions and fuel consumption related properties of components, separate technical units and systems

1. The manufacturer shall notify the approval authority of any changes to the design or the manufacturing process of components, separate technical units or systems concerned which occur after the certification of the values relating to the CO_2 emissions and fuel consumption related properties of the relevant component family, separate technical unit family or system family pursuant to Article 17 and which may have a non-negligible effect on the CO_2 emissions and fuel consumption related properties of those components, separate technical units and systems.

2. Upon receipt of the notification referred to in paragraph 1, the approval authority shall inform the manufacturer whether or not the components, separate technical units or systems affected by the changes continue to be covered by the certificate issued, or whether additional testing in accordance with Article 14 is necessary in order to verify the impact of the changes on the CO_2 emissions and fuel consumption related properties of the components, separate technical units or systems concerned.

3. Where the components, separate technical units or systems affected by the changes are not covered by the certificate, the manufacturer shall, within one month of receipt of that information from the approval authority, apply for a new certification or an extension pursuant to Article 18. If the manufacturer does not apply for a new certification or an extension within that deadline, or if the application is rejected, the certificate shall be withdrawn.

CHAPTER 5

CONFORMITY OF SIMULATION TOOL OPERATION, INPUT INFORMATION AND INPUT DATA

Article 20

▼M1

Responsibilities of the vehicle manufacturer, the approval authority and the Commission with regard to the conformity of simulation tool operation

▼B

1. ►M3 The vehicle manufacturer shall take the necessary measures to ensure that the processes set up for the purpose of obtaining the licence for the simulation tool for the application case covered by the licence granted pursuant to Article 7 continue to be adequate for that purpose. ◄

▼M1

►M3 For medium lorries and heavy lorries, with the exception of He-HDV or PEV, the vehicle manufacturer shall, perform the verification testing procedure set out in Annex Xa on a minimum number of vehicles in accordance with that Annex, point 3. ◄ The vehicle manufacturer shall provide, until 31 December of each year and in accordance with point 8 of Annex Xa, a test report to the approval

▼M1

authority for each vehicle tested, shall keep the test reports for a duration of at least 10 years and shall make them available to the Commission and approval authorities of the other Member States upon request.

▼B

2. ►M3 The approval authority shall perform, four times per year, an assessment as referred to in point 2 of Annex II in order to verify whether the processes set up by the manufacturer for the purposes of determining CO_2 emissions and fuel consumption for all the application cases and vehicle groups covered by the licence continue to be adequate. ◄ The assessment shall also include verification of the selection of the input information and input data and repetition of the simulations performed by the manufacturer,

▼M1

Where a vehicle fails the verification testing procedure set out in Annex Xa, the approval authority shall start an investigation to determine the cause of that failure, in accordance with Annex Xa. As soon as the approval authority determines the cause of the failure, it shall inform the approval authorities of the other Member States thereof.

If the cause of the failure is linked to the operation of the simulation tool, Article 21 shall apply. If the cause of the failure is linked to the certified CO_2 emissions and fuel consumption related properties of components, separate technical units and systems, Article 23 shall apply.

If no irregularities could be found in the certification of components, separate technical units or systems and the operation of the simulation tool, the approval authority shall report the vehicle failure to the Commission. The Commission shall investigate whether the simulation tool or the verification testing procedure set out in Annex Xa has caused the vehicle to fail and whether an improvement of the simulation tool or the verification testing procedure is necessary.

▼B

Article 21

Remedial measures for the conformity of simulation tool operation

1. Where the approval authority finds, pursuant to Article 20(2), that the processes set up by the vehicle manufacturer for the purposes of determining the CO_2 emissions and fuel consumption of the vehicle groups concerned are not in accordance with the licence or with this Regulation or may lead to an incorrect determination of the CO_2 emissions and fuel consumption of the vehicles concerned, the approval authority shall request the manufacturer to submit a plan of remedial measures no later than 30 calendar days after receipt of the request from the approval authority.

Where the vehicle manufacturer demonstrates that further time is necessary for the submission of the plan of remedial measures, an extension of up to 30 calendar days may be granted by the approval authority.

▼M3

2. The plan of remedial measures shall apply to all application cases and vehicle groups which have been identified by the approval authority in its request.

▼B

3. The approval authority shall approve or reject the plan of remedial measures within 30 calendar days of its receipt. The approval authority shall notify the manufacturer and all the other Member States of its decision to approve or reject the plan of remedial measures.

▼M3

The approval authority may require the vehicle manufacturer to issue a new manufacturer's records file, vehicle information file, customer information file and certificate of conformity on the basis of a new determination of CO_2 emissions and fuel consumption reflecting the changes implemented in accordance with the approved plan of remedial measures.

The vehicle manufacturer shall take the necessary measures to ensure that the processes set up for the purpose of obtaining the licence to operate the simulation tool for all the application cases and vehicle groups covered by the licence granted pursuant to Article 7 continue to be adequate for that purpose.

For medium lorries and heavy lorries the vehicle manufacturer shall, perform the verification testing procedure set out in Annex Xa on a minimum number of vehicles in accordance with that Annex, point 3.

▼B

4. The manufacturer shall be responsible for the execution of the approved plan of remedial measures.

5. Where the plan of the remedial measures has been rejected by the approval authority, or the approval authority establishes that the remedial measures are not being correctly applied, it shall take the necessary measures to ensure the conformity of simulation tool operation, or withdraw the licence.

Article 22

Responsibilities of the manufacturer and approval authority with regards to conformity of CO_2 emissions and fuel consumption related properties of components, separate technical units and systems

1. ►M3 The manufacturer shall take the necessary measures in accordance with Annex IV to Regulation (EU) 2018/858 to ensure that the CO_2 emissions and fuel consumption related properties of the components, separate technical units and systems listed in Article 12(1) which have been the subject of certification in accordance with Article 17 do not deviate from the certified values. ◄

Those measures shall also include the following:

— the procedures laid down in Appendix 4 to Annex V as regards engines;

— the procedures laid down in point 7 of Annex VI as regards transmissions;

— the procedures laid down in point 5 and 6 of Annex VII as regards axles;

▼B

— the procedures laid down in Appendix 6 to Annex VIII as regards body or trailer air drag;

— the procedures laid down in point 4 of Annex X as regards tyres;

▼M3

— the procedures laid down in points 1 to 4 of Appendix 12 to Annex Xb as regards electric powertrain components.

▼B

Where CO_2 emissions and fuel consumption related properties of a member of a component family, separate technical unit family or system family have been certified in accordance with Article 15(5), the reference value for the verification of the CO_2 emissions and fuel consumption related properties shall be the one certified for this family member.

Where a deviation from the certified values is identified as a result of the measures referred to in the first and second subparagraphs, the manufacturer shall immediately inform the approval authority thereof.

2. The manufacturer shall provide, on an annual basis, testing reports containing the results of the procedures referred to in the second subparagraph of paragraph 1 to the approval authority which certified the CO_2 emissions and fuel consumption related properties of the component family, separate technical unit family or system family concerned. The manufacturer shall make the test reports available to the Commission upon request.

▼M3

3. The manufacturer shall ensure that at least one in every 25 procedures referred to in the second subparagraph of paragraph 1, or, with an exception for tyres, at least one procedure per year, relating to a component, separate technical unit and system, or if applicable their respective families is supervised by a different approval authority than the one which participated in the certification of CO_2 emissions and fuel consumption related properties of the component, separate technical unit, system or if applicable their respective families concerned pursuant to Article 16.

▼B

4. Any approval authority may at any time perform verifications relating to the components, separate technical units and systems at any of the manufacturer's and vehicle manufacturer's facilities in order to verify whether the CO_2 emissions and fuel consumption related properties of those components, separate technical units and systems do not deviate from the certified values.

The manufacturer and the vehicle manufacturer shall provide the approval authority within 15 working days of the approval authority's request with all the relevant documents, samples and other materials in his possession and necessary to perform the verifications relating to a component, separate technical unit or system.

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Article 23

Remedial measures for the conformity of CO_2 emissions and fuel consumption related properties of components, separate technical units and systems

▼M1

1. Where the approval authority finds, pursuant to Articles 20 and 22, that the measures taken by the manufacturer to ensure that the CO_2 emissions and fuel consumption related properties of the components, separate technical units and systems listed in Article 12(1) and which have been the subject of certification in accordance with Article 17 do not deviate from the certified values are not adequate, the approval authority shall request the manufacturer to submit a plan of remedial measures no later than 30 calendar days after receipt of the request from the approval authority.

▼B

Where the manufacturer demonstrates that further time is necessary for the submission of the plan of remedial measures, an extension of up to 30 calendar days may be granted by the approval authority.

▼M3

2. The plan of remedial measures shall apply to all the components, separate technical units and systems, or if applicable their respective families which have been identified by the approval authority in its request.

▼B

3. The approval authority shall approve or reject the plan of remedial measures within 30 calendar days of its receipt. The approval authority shall notify the manufacturer and all the other Member States of its decision to approve or reject the plan of remedial measures.

▼M3

The approval authority may require the vehicle manufacturer to issue a new manufacturer's records file, customer information file, vehicle information file and certificate of conformity on the basis of a new determination of CO_2 emissions and fuel consumption reflecting the changes implemented in accordance with the approved plan of remedial measures.

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4. The manufacturer shall be responsible for the execution of the approved plan of remedial measures.

▼M3

5. The manufacturer shall keep a record of every component, separate technical unit or system recalled and repaired or modified and of the workshop which performed the repair or modification. The approval authority shall have access to such records on request during the implementation of the plan of the remedial measures and for a period of 5 years after the completion of its implementation.

The manufacturer shall store those records for 10 years.

6. Where the plan of remedial measures has been rejected by the approval authority, or the approval authority establishes that the remedial measures are not being correctly applied, it shall take the necessary measures to ensure the conformity of CO_2 emissions and fuel consumption related properties of the component, separate technical unit and system, and if applicable their respective families concerned, or withdraw the certificate on CO_2 emissions and fuel consumption related properties.

▼B

CHAPTER 6

FINAL PROVISIONS

Article 24

Transitional provisions

1. ►M3 Without prejudice to Article 10(3) of this Regulation, where the obligations referred to in Article 9 of this Regulation have not been complied with, Member States shall consider certificates of conformity for type approved vehicles to be no longer valid for the purposes of Article 48 of Regulation (EU) 2018/858, and, for type approved and individually approved vehicles, shall prohibit the registration, sale or entry into service of: ◄

▼M1

(a) vehicles in the groups 4, 5, 9 and 10, including the sub-group 'v' in each vehicle group, as defined in Table 1 of Annex I, as from 1 July 2019;

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(b) vehicles in the groups 1, 2, and 3, as defined in Table 1 of Annex I, as from 1 January 2020;

(c) vehicles in the groups 11, 12 and 16, as defined in Table 1 of Annex I, as from 1 July 2020;

▼M3

(d) vehicles in the groups 53 and 54, as defined in Table 2 of Annex I as from 1 July 2024;

(e) vehicles in the groups 31 to 40, as defined in Tables 4 to 6 of Annex I, as from 1 January 2025;

(f) vehicles in the group 1s as defined in Table 1 of Annex I, as from 1 July 2024.

2. The obligations referred to in Article 9 shall apply as follows:

(a) for vehicles in the groups 53 and 54, as defined in Table 2 of Annex I, with production date on or after 1 January 2024;

(b) for vehicles in the groups P31/32, P33/34, P35/36, P37/38 and P39/40 as defined in Table 3 of Annex I with production date on or after 1 January 2024;

(c) for heavy buses the simulation of the complete vehicle or completed vehicle as referred in point 2.1(b) of Annex I shall only be performed if the simulation of the primary vehicle as referred in point 2.1(a) of Annex I is available;

(d) for vehicles in the group 1s as defined in Table 1 of Annex I with production date on or after 1 January 2024;

(e) for vehicles in the groups 1, 2, 3, 4, 5, 9, 10, 4v, 5v, 9v, 10v, 11, 12, and 16, as defined in Table 1 of Annex I, other than those defined in points (f) and (g) of this paragraph, with production date on or after 1 January 2024;

▼**M3**

(f) for vehicles in the groups 1, 2, 3, 4, 5, 9, 10, 4v, 5v, 9v, 10v, 11, 12, and 16, as defined in Table 1 of Annex I, which are equipped with a waste heat recovery system, as defined in point 2(8) of Annex V, provided that they are not ZE-HDVs, He-HDVs or dual-fuel vehicles;

(g) for dual-fuel vehicles in the groups 1, 2, 3, 4, 5, 9, 10, 4v, 5v, 9v, 10v, 11, 12, and 16 as defined in Table 1 of Annex I with production date on or after 1 January 2024; if they have a production date before 1 January 2024, the manufacturer may choose whether to apply Article 9.

For ZE-HDVs, He-HDVs and dual-fuel vehicles in the groups 1, 2, 3, 4, 5, 9, 10, 4v, 5v, 9v, 10v, 11, 12, and 16 as defined in Table 1 of Annex I in respect of which Article 9 has not been applied in conformity with points (a) to (g) of the first subparagraph of this paragraph, the vehicle manufacturer shall determine the input parameters specified for those vehicles in the models set out in Annex III, Table 5, using the latest available version of the simulation tool referred to in Article 5(3). In such case, the obligations referred to in Article 9 shall be deemed to be fulfilled for the purposes of paragraph 1 of this Article.

For the purposes of this paragraph, the production date shall mean the date of signature of the certificate of conformity and where no certificate of conformity has been issued, the date on which the vehicle identification number was affixed for the first time on the relevant parts of the vehicle.

3. Remedial measures under Articles 21(5) and 23(6) shall apply with regard to vehicles referred to in paragraph 1, points (a), (b) and (c), of this Article pursuant to an investigation into a vehicle failure in the verification testing procedure set out in Annex Xa as from 1 July 2023 and with regard to vehicles referred to in paragraph 2, points (d) and (g), of this Article as from 1 July 2024.

▼**B**

Article 25

Amendment to Directive 2007/46/EC

Annexes I, III, IV, IX and XV to Directive 2007/46/EC are amended in accordance with Annex XI to this Regulation.

Article 26

Amendment to Regulation (EU) No 582/2011

Regulation (EU) No 582/2011 is amended as follows:

(1) In Article 3(1), the following subparagraph is added:

‘In order to receive an EC type-approval of a vehicle with an approved engine system with regard to emissions and vehicle repair and maintenance information, or an EC type-approval of

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a vehicle with regard to emissions and vehicle repair and maintenance information, the manufacturer shall also demonstrate that the requirements laid down in Article 6 and Annex II to Commission Regulation (EU) 2017/2400 (*) are met with respect to the vehicle group concerned. However, that requirement shall not apply where the manufacturer indicates that new vehicles of the type to be approved will not be registered, sold or put into service in the Union on or after the dates laid down in points (a), (b) and (c) of paragraph 1 of Article 24 of Regulation (EU) 2017/2400 for the respective vehicle group.

(*) 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 CO_2 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 (OJ L 349, 29.12.2017, p. 1).';

(2) Article 8 is amended as follows:

(a) in paragraph 1a, point (d) is replaced by the following:

'(d) all other exceptions set out in points 3.1 of Annex VII to this Regulation, points 2.1 and 6.1 of Annex X to this Regulation, points 2.1, 4.1, 5.1, 7.1, 8.1 and 10.1 of Annex XIII to this Regulation, and point 1.1 of Appendix 6 to Annex XIII to this Regulation apply;';

(b) in paragraph 1a, the following point is added:

'(e) the requirements laid down in Article 6 and Annex II to Regulation (EU) 2017/2400 are met with respect to the vehicle group concerned, except where the manufacturer indicates that new vehicles of the type to be approved will not be registered, sold or put into service in the Union on or after the dates laid down in points (a), (b) and (c) of paragraph 1 of Article 24 of that Regulation for the respective vehicle group.';

(3) Article 10 is amended as follows:

(a) in paragraph 1a, point (d) is replaced by the following:

'(d) all other exceptions set out in points 3.1 of Annex VII to this Regulation, points 2.1 and 6.1 of Annex X to this Regulation, points 2.1, 4.1, 5.1, 7.1, 8.1 and 10.1.1 of Annex XIII to this Regulation, and point 1.1 of Appendix 6 to Annex XIII to this Regulation apply;';

▼B

(b) in paragraph 1a, the following point is added:

‘(e) the requirements laid down in Article 6 and Annex II to Regulation (EU) 2017/2400 are met with respect to the vehicle group concerned, except where the manufacturer indicates that new vehicles of the type to be approved will not be registered, sold or put into service in the Union on or after the dates laid down in points (a), (b) and (c) of paragraph 1 of Article 24 of that Regulation for the respective vehicle group.’.

Article 27

Entry into force

This Regulation shall enter into force on the twentieth day following that of its publication in the *Official Journal of the European Union*.

This Regulation shall be binding in its entirety and directly applicable in all Member States.

▼M3

ANNEX I

CLASSIFICATION OF VEHICLES IN VEHICLE GROUPS AND METHOD TO DETERMINE CO_2 EMISSIONS AND FUEL CONSUMPTION FOR HEAVY BUSES

1. Classification of the vehicles for the purpose of this Regulation

1.1 Classification of vehicles of category N

Table 1

Vehicle groups for heavy lorries

Description of elements relevant to the classification in vehicle groups				Allocation of mission profile and vehicle configuration						
Axle configuration	Chassis configuration	Technically permissible maximum laden mass (tons)	Vehicle group	Long haul	Long haul (EMS)	Regional delivery	Regional delivery (EMS)	Urban delivery	Municipal utility	Construction
4 × 2	Rigid lorry (or tractor) (**)	> 7,4 – 7,5	1s			R		R		
	Rigid lorry (or tractor) (**)	> 7,5 – 10	1			R		R		
	Rigid lorry (or tractor) (**)	> 10 – 12	2	R + T1		R		R		
	Rigid lorry (or tractor) (**)	> 12 – 16	3			R		R		
	Rigid lorry	> 16	4	R + T2		R		R	R	
	Tractor	> 16	5	T + ST	T + ST + T2	T + ST	T + ST + T2	T + ST		
	Rigid lorry	> 16	4v (***)						R	R
	Tractor	> 16	5v (***)							T + ST
4 × 4	Rigid lorry	> 7,5 – 16	(6)							
	Rigid lorry	> 16	(7)							
	Tractor	> 16	(8)							
6 × 2	Rigid lorry	all weights	9	R + T2	R + D + ST	R	R + D + ST		R	
	Tractor	all weights	10	T + ST	T + ST + T2	T + ST	T + ST + T2			
	Rigid lorry	all weights	9v (***)						R	R
	Tractor	all weights	10v (***)							T + ST

▼**M3**

Description of elements relevant to the classification in vehicle groups			Vehicle group	Allocation of mission profile and vehicle configuration						
Axle configuration	Chassis configuration	Technically permissible maximum laden mass (tons)		Long haul	Long haul (EMS)	Regional delivery	Regional delivery (EMS)	Urban delivery	Municipal utility	Construction
6 × 4	Rigid lorry	all weights	11	R + T2	R + D + ST	R	R + D + ST		R	R
	Tractor	all weights	12	T + ST	T + ST + T2	T + ST	T + ST + T2			T + ST
6 × 6	Rigid lorry	all weights	(13)							
	Tractor	all weights	(14)							
8 × 2	Rigid lorry	all weights	(15)							
8 × 4	Rigid lorry	all weights	16							R
8 × 6 8 ×8	Rigid lorry	all weights	(17)							
8 × 2 8 × 4 8 × 6 8 × 8	Tractor	all weights	(18)							
5 axles, all configurations	Rigid lorry or tractor	all weights	(19)							

(*) EMS — European Modular System
(**) In these vehicle classes tractors are treated as rigid lorries but with specific curb weight of tractor.
(***) Sub-group ‘v’ of vehicle groups 4, 5, 9 and 10: these mission profiles are exclusively applicable to vocational vehicles.

T = Tractor

R = Rigid lorry & standard body

T1, T2 = Standard trailers

ST = Standard semitrailer

D = Standard dolly

▼**M3**

Table 2

Vehicle groups for medium lorries

Description of elements relevant to the classification in vehicle groups			Allocation of mission profile and vehicle configuration						
Axle configuration	Chassis configuration	Vehicle group	Long haul	Long haul EMS (*)	Regional delivery	Regional delivery EMS (*)	Urban delivery	Municipal utility	Construction
FWD / 4 × 2F	Rigid Lorry (or tractor)	(51)							
	Van	(52)							
RWD / 4 × 2	Rigid Lorry (or tractor)	53			R		R		
	Van	54			I		I		
AWD / 4 × 4	Rigid Lorry (or tractor)	(55)							
	Van	(56)							

(*) EMS - European Modular System
R = Standard body
I = Van with its integrated body
FWD = Front wheel driven
RWD = Single driven axle which is not the front axle
AWD = More than a single driven axle

1.2. Classification of vehicles of category M

1.2.1. Heavy buses

1.2.2. Classification of primary vehicles

Table 3

Vehicle groups for primary vehicles

Description of elements relevant to the classification in vehicle groups		Vehicle group (1)	Allocation of generic body		Vehicle sub-group	Allocation of mission profile				
Number of axles	Artic-ulated		Low floor (LF) / High floor (HF) (2)	Number of decks (3)		Heavy Urban	Urban	Suburban	Interurban	Coach
2	no	P31/32	LF	SD	P31 SD	x	x	x	x	
				DD	P31 DD	x	x	x		
			HF	SD	P32 SD				x	x
				DD	P32 DD				x	x

▼**M3**

Description of elements relevant to the classification in vehicle groups		Vehicle group ([1])	Allocation of generic body		Vehicle sub-group	Allocation of mission profile				
Number of axles	Artic-ulated		Low floor (LF) / High floor (HF) ([2])	Number of decks ([3])		Heavy Urban	Urban	Suburban	Interurban	Coach
3	no	P33/34	LF	SD	P33 SD	x	x	x	x	
				DD	P33 DD	x	x	x		
			HF	SD	P34 SD				x	x
				DD	P34 DD				x	x
	yes	P35/36	LF	SD	P35 SD	x	x	x	x	
				DD	P35 DD	x	x	x		
			HF	SD	P36 SD				x	x
				DD	P36 DD				x	x
4	no	P37/38	LF	SD	P37 SD	x	x	x	x	
				DD	P37 DD	x	x	x		
			HF	SD	P38 SD				x	x
				DD	P38 DD				x	x
	yes	P39/40	LF	SD	P39 SD	x	x	x	x	
				DD	P39 DD	x	x	x		
			HF	SD	P40 SD				x	x
				DD	P40 DD				x	x

([1]) ‘P’ indicates the primary stage of the classification; the two numbers separated by the slash indicate the numbers for vehicle groups the vehicle can be allocated in the complete or completed stage.
([2]) ‘Low floor’ means vehicle codes ‘CE’, ‘CF’, ‘CG’, ‘CH’, as set out in point 3 of part C of Annex I to Regulation (EU) 2018/858.
‘High floor’ means vehicle codes ‘CA’, ‘CB’, ‘CC’, ‘CD’, as set out in point 3 of part C of Annex I to Regulation (EU) 2018/858.
([3]) ‘SD’ means single deck vehicle, ‘DD’ means double deck.

1.2.3. Classification of complete vehicles or completed vehicles

The classification of complete or completed vehicles that are heavy buses is based on the following six criteria:

(a) Number of axles;

(b) Vehicle code as set out in Annex I, part C, point 3, to Regulation (EU) 2018/858;

(c) Class of vehicle in accordance with paragraph 2 of UN Regulation No. 107 ([1]);

(d) Low entry vehicle (‘yes/no’ information derived from vehicle code and type of axle) to be determined according the decision flow shown in Figure 1;

(e) Number of passengers in lower deck from the Certificate of Conformity as set out in Annex VIII to Commission Implementing Regulation (EU) 2020/683 ([2]) or equivalent documents in the case of individual vehicle approval;

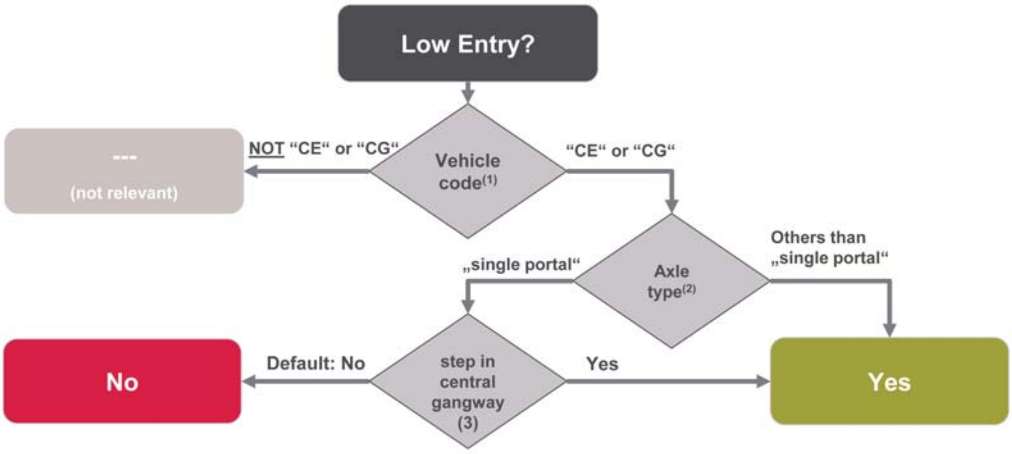
([1]) UN Regulation No. 107 of the Economic Commission for Europe of the United Nations (UNECE) – Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction (OJ L 52, 23.2.2018, p. 1).
([2]) Commission Implementing Regulation (EU) 2020/683 of 15 April 2020 implementing Regulation (EU) 2018/858 of the European Parliament and of the Council with regards to the administrative requirements for the approval and market surveillance of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (OJ L 163, 26.5.2020, p. 1).

▼**M3**

(f) Height of the integrated body to be determined in accordance with Annex VIII.

Figure 1

Decision flow to determine whether a vehicle is 'low entry' or not:



(1) Vehicle code as set out in point 3 of part C of Annex I to Regulation (EU) 2018/858 ("CE": Low Floor Single-Deck; "CG": Low Floor Single-Deck Articulated)

(2) Axle type according to point 2 of Annex VII of Regulation (EU) 2017/2400

(3) Low floor vehicle (according to point 3 of part C of Annex I to Regulation (EU) 2018/858) with at least one step (according to UN Regulation No 107, Annex 3, point 7.7.7 and Annex 4, Figure 8) in the central "gangway" (acc. to UN Regulation No 107, Definitions 2.15, 2.15.1, 2.15.2, 2.15.3 and Annex 4, Figure 25) in front of the (foremost) driven axle.

The corresponding classification to be used is given in Tables 4, 5 and 6.

Table 4

Vehicle groups for complete vehicles and completed vehicles that are heavy buses with 2 axles

Description of elements relevant to the classification in vehicle groups														Vehicle group	Allocation of mission profile				
Number of Axles	Chassis configuration (explanation only)			Vehicle Code (*)	Class of vehicle (**)					Low Entry (Vehicle Code CE or CG only)	Passenger seats in lower deck (Vehicle Code CB or CD only)	Height of the integrated body in [mm] (Vehicles Class 'II+III' only)			Heavy Urban	Urban	Suburban	Interurban	Coach
					I	I +II or A	II	II +III	III or B										
2	rigid	LF	SD	CE	x	x	x			no	—	—		31a	x	x	x		
					x	x				yes	—	—		31b1	x	x	x		
							x			yes	—	—		31b2	x	x	x	x	
			DD	CF	x	x	x			—	—	—		31c	x	x	x		
		open top	SD	CI	x	x	x	x	x	—	—	—		31d	x	x	x		
			DD	CJ	x	x	x	x	x	—	—	—		31e	x	x	x		
		HF	SD	CA			x			—	—	—		32a				x	x
								x		—	—	≤ 3 100		32b				x	x
								x		—	—	> 3 100		32c				x	x

▼**M3**

Number of Axles	Chassis configuration (explanation only)			Vehicle Code (*)	Class of vehicle (**) I	Class of vehicle (**) I +II or A	Class of vehicle (**) II	Class of vehicle (**) II +III	Class of vehicle (**) III or B	Low Entry (Vehicle Code CE or CG only)	Passenger seats in lower deck (Vehicle Code CB or CD only)	Height of the integrated body in [mm] (Vehicles Class 'II+III' only)	Vehicle group	Allocation of mission profile: Heavy Urban	Urban	Suburban	Interurban	Coach
									x	—	—	—	32d				x	x
			DD	CB			x	x	x	—	≤ 6	—	32e				x	x
							x	x	x	—	> 6	—	32f				x	x

(*) In accordance with Regulation (EU) 2018/858.
(**) In accordance with paragraph 2 of UN Regulation No. 107.

Table 5

Vehicle groups for complete vehicles and completed vehicles that are heavy buses with 3 axles

Number of Axles	Chassis configuration (explanation only)			Vehicle Code (*)	Class of vehicle (**) I	Class of vehicle (**) I +II or A	Class of vehicle (**) II	Class of vehicle (**) II + III	Class of vehicle (**) III or B	Low Entry (Vehicle Code CE or CG only)	Passenger seats in lower deck (Vehicle Code CB or CD only)	Height of the integrated body in [mm] (Vehicles Class 'II+III' only)	Vehicle group	Allocation of mission profile: Heavy Urban	Urban	Suburban	Interurban	Coach
3	rigid	LF	SD	CE	x	x	x			no	—	—	33a	x	x	x		
					x	x				yes	—	—	33b1	x	x	x		
							x			yes	—	—	33b2	x	x	x	x	
			DD	CF	x	x	x			—	—	—	33c	x	x	x		
		open top	SD	CI	x	x	x	x	x	—	—	—	33d	x	x	x		
			DD	CJ	x	x	x	x	x	—	—	—	33e	x	x	x		
		HF	SD	CA			x			—	—	—	34a				x	x
								x		—	—	≤ 3 100	34b				x	x
								x		—	—	> 3 100	34c				x	x
									x	—	—	—	34d				x	x
			DD	CB			x	x	x	—	≤ 6	—	34e				x	x
							x	x	x	—	> 6	—	34f				x	x

▼M3

Description of elements relevant to the classification in vehicle groups													Vehicle group	Allocation of mission profile				
Number of Axles	Chassis configuration (explanation only)			Vehicle Code (*)	Class of vehicle (**)					Low Entry (Vehicle Code CE or CG only)	Passenger seats in lower deck (Vehicle Code CB or CD only)	Height of the integrated body in [mm] (Vehicles Class 'II+III' only)						
					I	I +II or A	II	II + III	III or B					Heavy Urban	Urban	Suburban	Interurban	Coach
	articu-lated	LF	SD	CG	x	x	x			no	—	—	35a	x	x	x		
					x	x				yes	—	—	35b1	x	x	x		
							x			yes	—	—	35b2	x	x	x	x	
			DD	CH	x	x	x			—	—	—	35c	x	x	x		
		HF	SD	CC			x			—	—	—	36a				x	x
								x		—	—	≤ 3 100	36b				x	x
			SD					x		—	—	> 3 100	36c				x	x
									x	—	—	—	36d				x	x
			DD	CD			x	x	x	—	≤ 6	—	36e				x	x
							x	x	x	—	> 6	—	36f				x	x

(*) In accordance with Regulation (EU) 2018/858.
(**) In accordance with paragraph 2 of UN Regulation No. 107.

Table 6

Vehicle groups for complete vehicles and completed vehicles that are heavy buses with 4 axles

Description of elements relevant to the classification in vehicle groups													Vehicle group	Allocation of mission profile				
Number of Axles	Chassis configuration (explanation only)			Vehicle Code (*)	Class of vehicle (**)					Low Entry (Vehicle Code CE or CG only)	Passenger seats in lower deck (Vehicle Code CB or CD only)	Height of the integrated body in [mm] (Vehicles Class 'II+III' only)						
					I	I +II or A	II	II +III	III or B					Heavy Urban	Urban	Suburban	Interurban	Coach
4	rigid	LF	SD	CE	x	x	x			no	—	—	37a	x	x	x		
					x	x				yes	—	—	37b1	x	x	x		
							x			yes	—	—	37b2	x	x	x	x	
			DD	CF	x	x	x			—	—	—	37c	x	x	x		
		open top	SD	CI	x	x	x	x	x	—	—	—	37d	x	x	x		
			DD	CJ	x	x	x	x	x	—	—	—	37e	x	x	x		

▼**M3**

Description of elements relevant to the classification in vehicle groups													Vehicle group	Allocation of mission profile				
Number of Axles	Chassis configuration (explanation only)			Vehicle Code (*)	Class of vehicle (**)					Low Entry (Vehicle Code CE or CG only)	Passenger seats in lower deck (Vehicle Code CB or CD only)	Height of the integrated body in [mm] (Vehicles Class 'II+III' only)						
					I	I +II or A	II	II +III	III or B					Heavy Urban	Urban	Suburban	Interurban	Coach
		HF	SD	CA			x			—	—	—	38a				x	x
		HF	SD	CA				x		—	—	≤ 3 100	38b				x	x
		HF	SD	CA				x		—	—	> 3 100	38c				x	x
		HF	SD	CA					x	—	—	—	38d				x	x
		HF	DD	CB			x	x	x	—	≤ 6	—	38e				x	x
		HF	DD	CB			x	x	x	—	> 6	—	38f				x	x
	articulated	LF	SD	CG	x	x	x			no	—	—	39a	x	x	x		
	articulated	LF	SD	CG	x	x				yes	—	—	39b1	x	x	x		
	articulated	LF	SD	CG			x			yes	—	—	39b2	x	x	x	x	
	articulated	LF	DD	CH	x	x	x			—	—	—	39c	x	x	x		
	articulated	HF	SD	CC			x			—	—	—	40a				x	x
	articulated	HF	SD	CC				x		—	—	≤ 3 100	40b				x	x
	articulated	HF	SD	CC				x		—	—	> 3 100	40c				x	x
	articulated	HF	SD	CC					x	—	—	—	40d				x	x
	articulated	HF	DD	CD			x	x	x	—	≤ 6	—	40e				x	x
	articulated	HF	DD	CD			x	x	x	—	> 6	—	40f				x	x

(*) In accordance with Regulation (EU) 2018/858.
(**) In accordance with paragraph 2 of UN Regulation No. 107.

2. Method to determine CO_2 emissions and fuel consumption for heavy buses

2.1. For heavy buses the vehicle specifications of the complete vehicle or completed vehicle including properties of the final bodywork and auxiliary units shall be reflected in the results for CO_2 emissions and fuel consumption. In the case of heavy buses built in steps, more than a single manufacturer may be involved in the process of generation of input data and input information and the operation of the simulation tool. For heavy buses the CO_2 emissions and fuel consumption shall be based on the following two different simulations:

(a) for the primary vehicle;

(b) for the complete vehicle or completed vehicle.

2.2. If a heavy bus is approved by a manufacturer as a complete vehicle, the simulations shall be performed for both the primary vehicle and the complete vehicle.

▼**M3**

2.3. For the primary vehicle the input to the simulation tool covers input data regarding the engine, transmission, tyres and input information for a subset of auxiliary units (3). The classification into vehicle groups is performed in accordance with Table 3 based on the number of axles and the information whether the vehicle is an articulated bus or not. In the simulations for the primary vehicle the simulation tool allocates a set of four different generic bodies (high floor and low floor, single deck and double deck bodywork) and simulates the 11 mission profiles as listed in Table 3 for each vehicle group for two different loading conditions. This leads to a set of 22 results for CO_2 emissions and fuel consumption for a primary heavy bus. The simulation tool produces the vehicle information file for the initial step (VIF_1), which contains all necessary data to be handed over to the subsequent manufacturing step. The VIF_1 comprises all non-confidential input data, the results for energy consumption (4) in [MJ/km], information on the primary manufacturer and the relevant hashes (5).

2.4. The manufacturer of the primary vehicle shall make the VIF_1 available to the manufacturer responsible for the subsequent manufacturing step. Where a manufacturer of a primary vehicle provides data going beyond the primary vehicle requirements as set out in Annex III, this data does not influence the simulation results for the primary vehicle but is written into the VIF_1 to be considered in later steps. For a primary vehicle the simulation tool furthermore produces a manufacturer's records file.

2.5. In the case of an interim vehicle, the interim manufacturer is responsible for a sub-set of relevant input data and input information for the final bodywork (6). An interim manufacturer does not apply for certification of the completed vehicle. An interim manufacturer shall add or update information relevant for the completed vehicle and operate the simulation tool to produce an updated and hashed version of the vehicle information file (VIF_i) (7). The VIF_i shall be made available to the manufacturer responsible for the subsequent manufacturing step. For interim vehicles the VIF_i also covers the task of documentation towards approval authorities. No simulations of CO_2 emissions and/or fuel consumption are performed on interim vehicles.

2.6. If a manufacturer performs modifications to an interim, complete or completed vehicle, which would require updates to the input data or the input information allocated to the primary vehicle (e.g. a change of an axle or of tyres), the manufacturer performing the modification acts as a primary vehicle manufacturer with the corresponding responsibilities.

2.7. For a complete or completed vehicle the manufacturer shall complement and, if necessary, update the input data and input information for the final bodywork as transmitted in the VIF_i from the previous manufacturing step and shall operate the simulation tool to calculate the CO_2 emissions and fuel consumption. For the simulations at this stage, heavy buses are classified based on the six criteria set out in point 1.2.3 into the vehicle groups as listed in Tables 4, 5 and 6. To determine CO_2 emissions and fuel consumption of complete vehicles or completed vehicles that are heavy buses the simulation tool performs the following calculation steps:

(3) Input information and input data as defined in Annex III for primary vehicles.

(4) The results for CO_2 emissions and fuel consumption do not need to be submitted via the VIF, as this information can be calculated from results for energy consumption and the known fuel type.

(5) The content of the VIF is specified in detail in Annex IV, Part III.

(6) Subset for input information and input data as defined in Annex III for complete and completed vehicles.

(7) 'i' represents the number of manufacturing steps involved in the process so far.

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2.7.1. Step 1 - Selection of the primary vehicle sub-group which matches the bodywork of the complete or completed vehicle (e.g. 'P34 DD' for '34f') and making available the corresponding results for energy consumption from the primary vehicle simulation.

2.7.2. Step 2 - Performing simulations to quantify the influence of the bodywork and auxiliaries of the complete vehicle or completed vehicle compared to the generic bodywork and auxiliaries, as considered in the simulations for the primary vehicle regarding energy consumption. In these simulations, generic data are used for the set of primary vehicle data, which are not part of the information transfer between different manufacturing steps as provided by the VIF ([8]).

2.7.3. Step 3 - Combining energy consumption results from the primary vehicle simulation as made available by step 1 with the results from step 2 provides the energy consumption results of the complete or completed vehicle. The details of this calculation step are documented in the user manual of the simulation tool.

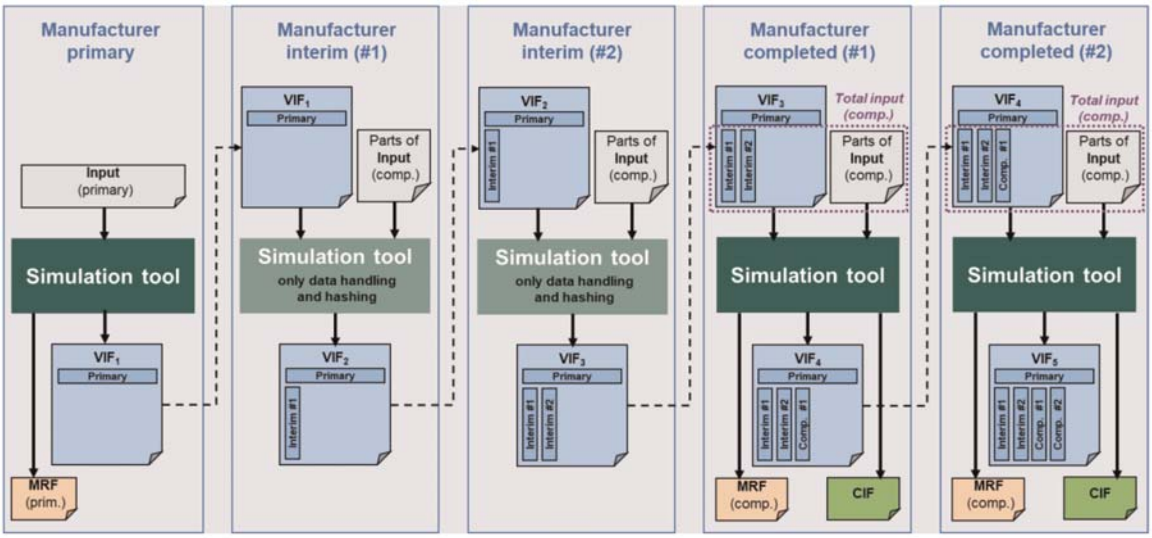
2.7.4. Step 4 - Results for CO_2 emissions and fuel consumption of the vehicle are calculated based on the results of step 3 and the generic fuel specifications as stored in the simulation tool. Steps 2, 3 and 4 are performed separately for each combination of mission profile as listed in the Tables 4, 5 and 6 for the vehicle groups in both low and representative loading condition.

2.7.5. For a complete vehicle or completed vehicle the simulation tool produces a manufacturer's records file, a customer information file as well as a VIF_i. The VIF_i shall be made available to the subsequent manufacturer in the event the vehicle undergoes a further step to be completed.

Figure 2 shows the data flow based on the example of a vehicle produced in five CO_2 related manufacturing steps.

Figure 2

Example of data flow in the case of a heavy bus manufactured in five steps



([8]) See Annex IV, Part III, point 1.1.

▼B

ANNEX II

REQUIREMENTS AND PROCEDURES RELATED TO THE OPERATION OF THE SIMULATION TOOL

1. The processes to be set up by the vehicle manufacturer with a view to the operation of the simulation tool

1.1. The manufacturer shall set up at least the following processes:

1.1.1 A data management system covering sourcing, storing, handling and retrieving of the input information and input data for the simulation tool as well as handling certificates on the CO_2 emissions and fuel consumption related properties of a component families, separate technical unit families and system families. The data management system shall at least:

(a) ensure application of correct input information and input data to specific vehicle configurations

(b) ensure correct calculation and application of standard values;

▼M3

(c) verify by means of comparing cryptographic hashes that the input files of components, separate technical units, systems or if applicable their respective families, which are used for the simulation corresponds to the input data of the component, separate technical unit, system or if applicable their respective family for which the certification has been granted;

▼B

(d) include a protected database for storing the input data relating to the component families, separate technical unit families or system families and the corresponding certificates of the CO_2 emissions and fuel consumption related properties;

(e) ensure correct management of the changes of specification and updates of components, separate technical units and systems;

(f) enable tracing of the components, separate technical units and systems after the vehicle is produced.

1.1.2 A data management system covering retrieving of the input information and input data and calculations by means of the simulation tool and storing of the output data. The data management system shall at least:

(a) ensure a correct application of cryptographic hashes;

(b) include a protected database for storing the output data;

1.1.3 Process for consulting the dedicated electronic distribution platform referred to in Article 5(2) and Article 10(1) and (2), as well as downloading and installing the latest versions of the simulation tool.

1.1.4 Appropriate training of staff working with the simulation tool.

2. Assessment by the approval authority

2.1. The approval authority shall verify whether the processes set out in point 1 related to the operation of the simulation tool have been set up.

▼B

The approval authority shall also verify the following:

(a) the functioning of the processes set out in points 1.1.1, 1.1.2 and 1.1.3 and the application of the requirement set out in point 1.1.4;

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(b) that the processes used during the demonstration are applied in the same manner in all the production facilities manufacturing vehicles belonging to the application case concerned;

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(c) the completeness of the description of the data and process flows of operations related to the determination of the CO_2 emissions and fuel consumption of the vehicles.

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For the purpose of the second paragraph, point (a), the verification shall include determination of the CO_2 emissions and fuel consumption of at least one vehicle from each production facility for which the licence has been applied for.

▼B

Appendix 1

MODEL OF AN INFORMATION DOCUMENT FOR THE PURPOSES OF OPERATING THE SIMULATION TOOL WITH A VIEW TO DETERMINING THE CO_2 EMISSIONS AND FUEL CONSUMPTION OF NEW VEHICLES

SECTION I

▼M3

1 Name and address of vehicle manufacturer:

▼B

2 Assembly plants for which the processes referred to in point 1 of Annex II of Regulation (EU) 2017/2400 have been set up with a view to the operation of the simulation tool:

▼M3

3 Application case covered:

▼B

4 Name and address of the manufacturer's representative (if any)

SECTION II

1. Additional information

1.1 Data and process flow handling description (e.g. flow chart)

1.2 Description of quality management process

1.3 Additional quality management certificates (if any)

1.4 Description of simulation tool data sourcing, handling and storage

1.5 Additional documents (if any)

2. Date: ....

3. Signature: ....

▼B

Appendix 2

MODEL OF A LICENCE TO OPERATE THE SIMULATION TOOL WITH A VIEW TO DETERMINING CO_2 EMISSIONS AND FUEL CONSUMPTION OF NEW VEHICLES

Maximum format: A4 (210 × 297 mm)

LICENCE TO OPERATE THE SIMULATION TOOL WITH A VIEW TO DETERMINING CO_2 EMISSIONS AND FUEL CONSUMPTION OF NEW VEHICLES

Communication concerning:	Administration stamp

Communication concerning:
— granting [1]
— extension [1]
— refusal [1]
— withdrawal [1]

of the licence to operate simulation tool with regard to Regulation (EC) No 595/2009 as implemented by Regulation (EU) 2017/2400.

Licence number:

Reason for extension: ....

SECTION I

▼M3

0.1 Name and address of vehicle manufacturer:

0.2 Production facilities and/or assembly plants for which the processes referred to in point 1 of Annex II to Commission Regulation (EU) 2017/2400 [2] have been set up with a view to the operation of the simulation tool

0.3 Application case covered:

▼B

SECTION II

1. Additional information

1.1 Assessment report performed by an approval authority

1.2. Data and process flow handling description (e.g. flow chart)

1.3. Description of quality management process

1.4. Additional quality management certificates (if any)

1.5. Description of simulation tool data sourcing, handling and storage

1.6 Additional documents (if any)

2. Approval authority responsible for carrying out the assessment

3. Date of the assessment report

4. Number of assessment report report

5. Remarks (if any): see Addendum

6. Place

7. Date

8. Signature

(1) Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable)
(2) OJ L 349, 29.12.2017, p. 1.

▼M3

ANNEX III

INPUT INFORMATION RELATING TO THE CHARACTERISTIC OF THE VEHICLE

1. Introduction

This Annex describes the list of parameters to be provided by the vehicle manufacturer as input to the simulation tool. The applicable XML schema as well as example data are available at the dedicated electronic distribution platform.

2. Definitions

(1) ‘parameter ID’: Unique identifier as used in the simulation tool for a specific input parameter or set of input data.

(2) ‘type’: Data type of the parameter

string	sequence of characters in ISO8859-1 encoding
token	sequence of characters in ISO8859-1 encoding, no leading/trailing whitespace
date	date and time in UTC time in the format:YYYY-MM-DD*T*HH:MM:SS*Z* with italic letters denoting *fixed characters* e.g. ‘2002-05-30*T*09:30:10*Z*’
integer	value with an integral data type, no leading zeros, e.g. ‘1 800’
double, X	fractional number with exactly X digits after the decimal sign (‘.’) and no leading zeros e.g. for ‘double, 2’: ‘2 345,67’; for ‘double, 4’: ‘45.6780’.

(3) ‘unit’ .... physical unit of the parameter.

(4) ‘corrected actual mass of the vehicle’ means the mass as specified under the ‘actual mass of the vehicle’ in accordance with Commission Regulation (EU) No 1230/2012 (*) with an exception for the tank(s) which shall be filled to at least 50 % of its or their capacity/ies. The liquid containing systems are filled to 100 % of the capacity specified by the manufacturer, except the liquid containing systems for waste water that must remain empty.

For medium rigid lorries, heavy rigid lorries and tractors the mass is determined without superstructure and corrected by the additional weight of the non-installed standard equipment as specified in point 4.3. The mass of a standard body, standard semi-trailer or standard trailer to simulate the complete vehicle or complete vehicle-(semi-)trailer combination are added automatically by the simulation tool. All parts that are mounted on and above the main frame are regarded as superstructure parts if they are installed only for facilitating a superstructure, independent of the necessary parts for in running order conditions.

For heavy buses that are primary vehicles ‘corrected actual mass of the vehicle’ is not applicable as the generic mass value is allocated by the simulation tool.

(5) ‘height of the integrated body’ means the difference in ‘Z’-direction between the reference point ‘A’ of the highest point and lowest point ‘B’ of an integrated body (see Figure 1). For vehicles deviating from the standard case, the following cases are applicable (see Figure 2):

▼M3

Special case 1, two levels: Height of the integrated body is the average of h1 and h2, where

— h1 is the difference between point A, but determined in the cross section of the vehicle at the rear end of first passenger door, and point B

— h2 is the difference between point A and point B

Special case 2, inclined: Height of the integrated body is the average of h1 and h2, where

— h1 is the difference between point A, but determined in the cross section of the vehicle at the rear end of first passenger door, and point B

— h2 is the difference between point A and point B

Special case 3, open top with roof section:

— Height of the integrated body determined in the remaining roof section

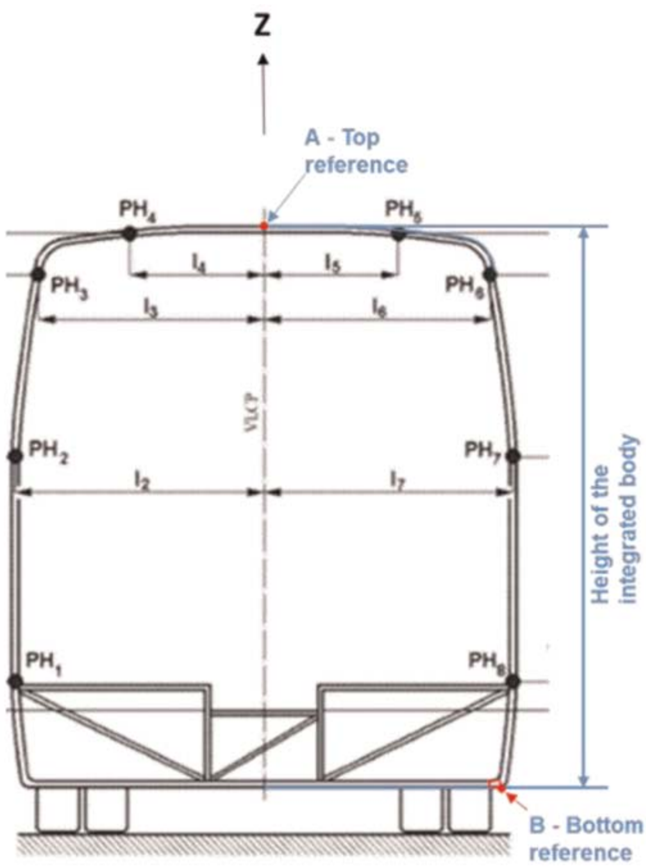
Special case 4, open top without any roof section:

— Height of the integrated body is the difference between the highest point of the vehicle within one meter in the longitudinal direction of the front screen or upper front screen, in the case of a double decker, and point B

For all other cases not covered by standard or special cases 1 to 4, the height of the integrated body is the difference between the highest point of the vehicle and point B. This parameter is relevant only for heavy buses.

Figure 1

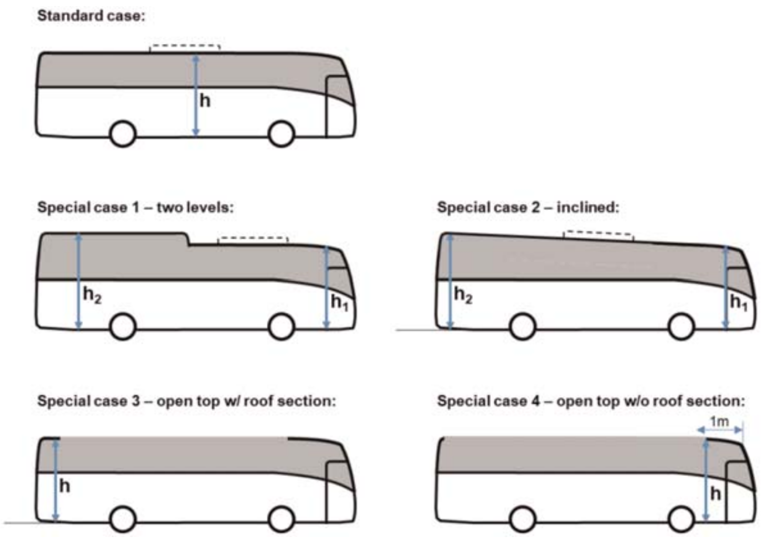
Height of the integrated body – standard case



▼M3

Figure 2

Height of the integrated body – special cases



(6) reference point 'A' means the highest point on the bodywork (Figure 1). Body and/or design panels, brackets for mounting e.g. HVAC systems, hatches and similar items shall not be considered.

(7) reference point 'B' means the lowest point on the lower outside edge of the bodywork (Figure 1). Brackets e.g. for axle mounting shall not be considered.

(8) 'vehicle length' means the vehicle dimension in accordance with Table I of Appendix 1 of Annex I to Regulation (EU) 1230/2012. Additionally, removable load carrier devices, non-removable coupling devices and any other non-removable exterior parts which do not affect the usable space for passengers shall not be taken into account. This parameter is relevant only for heavy buses.

(9) 'vehicle width' means the vehicle dimension in accordance with Table II of Appendix 1 of Annex I to Regulation (EU) 1230/2012. Deviating from these provisions and not to be considered are removable load carrier devices, non-removable coupling devices and any other non-removable exterior parts which do not affect the usable space for passengers.

(10) 'entrance height in non-kneeled position' means the floor level within the first door aperture above the ground, measured at the most forward door of the vehicle when the vehicle is in non-kneeled position.

(11) 'fuel cell' means an energy converter transforming chemical energy (input) into electrical energy (output) or vice versa.

(12) 'fuel cell vehicle' or 'FCV' means a vehicle equipped with a powertrain containing exclusively fuel cell(s) and electric machine(s) as propulsion energy converter(s).

(13) 'fuel cell hybrid vehicle' or 'FCHV' means a fuel cell vehicle equipped with a powertrain containing at least one fuel storage system and at least one rechargeable electric energy storage system as propulsion energy storage systems.

(14) 'pure ICE vehicle' means a vehicle where all of the propulsion energy converters are internal combustion engines.

▼**M3**

(15) 'electric machine' or 'EM' means an energy converter transforming between electrical and mechanical energy.

(16) 'energy storage system' means a system which stores energy and releases it in the same form as was input.

(17) 'propulsion energy storage system' means an energy storage system of the powertrain which is not a peripheral device and whose output energy is used directly or indirectly for the purpose of vehicle propulsion.

(18) 'category of propulsion energy storage system' means a fuel storage system, a rechargeable electric energy storage system (REESS), or a rechargeable mechanical energy storage system.

(19) 'downstream' means a position in the vehicle's powertrain that is closer to the wheels than the actual reference position.

(20) 'drivetrain' means the connected elements of the powertrain for transmission of the mechanical energy between the propulsion energy converter(s) and the wheels.

(21) 'energy converter' means a system where the form of energy output is different from the form of energy input.

(22) 'propulsion energy converter' means an energy converter of the powertrain which is not a peripheral device whose output energy is used directly or indirectly for the purpose of vehicle propulsion.

(23) 'category of propulsion energy converter' means an internal combustion engine, an electric machine, or a fuel cell.

(24) 'form of energy' means electrical energy, mechanical energy, or chemical energy (including fuels).

(25) 'fuel storage system' means a propulsion energy storage system that stores chemical energy as liquid or gaseous fuel.

(26) 'hybrid vehicle' or 'HV' means a vehicle equipped with a powertrain containing at least two different categories of propulsion energy converters and at least two different categories of propulsion energy storage systems.

(27) 'hybrid electric vehicle' or 'HEV' means a hybrid vehicle where one of the propulsion energy converters is an electric machine and the other one is an internal combustion engine.

(28) 'serial HEV' means a HEV with a powertrain architecture where the ICE powers one or more electrical energy conversion paths with no mechanical connection between the ICE and the wheels of the vehicle.

(29) 'internal combustion engine' or 'ICE' means an energy converter with intermittent or continuous oxidation of combustible fuel transforming between chemical and mechanical energy.

(30) 'off-vehicle charging hybrid electric vehicle' or 'OVC-HEV' means a hybrid electric vehicle that can be charged from an external source.

(31) 'parallel HEV' means a HEV with a powertrain architecture where the ICE powers only a single mechanically connected path between the engine and the wheels of the vehicle.

▼M3

(32) ‘peripheral devices’ means any energy consuming, converting, storing or supplying devices, where the energy is not directly or indirectly used for the purpose of vehicle propulsion but which are essential to the operation of the powertrain.

(33) ‘powertrain’ means the total combination in a vehicle of propulsion energy storage system(s), propulsion energy converter(s) and the drivetrain(s) providing the mechanical energy at the wheels for the purpose of vehicle propulsion, plus peripheral devices.

(34) ‘pure electric vehicle’ or ‘PEV’ means a motor vehicle pursuant to Regulation (EU) 2018/858, article 3(16), equipped with a powertrain containing exclusively electric machines as propulsion energy converters and exclusively rechargeable electric energy storage systems as propulsion energy storage systems and/or alternatively any other means for direct conductive or inductive supply of electric energy from the power network providing the propulsion energy to the motor vehicle.

(35) ‘upstream’ means a position in the vehicle’s powertrain that is further away from the wheels than the actual reference position.

(36) ‘IEPC’ means an integrated electric powertrain component in accordance with point 2(36) of Annex Xb.

(37) ‘IHPC Type 1’ means an integrated hybrid electric vehicle powertrain component Type 1 in accordance with point 2(38) of Annex Xb.

3. Set of input parameters

In Tables 1 to 11 the sets of input parameters to be provided regarding the characteristics of the vehicle are specified. Different sets are defined depending on the application case (medium lorries, heavy lorries and heavy buses).

For heavy buses a differentiation is made between input parameters to be provided for the simulations at the primary vehicle and for the simulations at the complete vehicle or completed vehicle. The following provisions shall apply:

— Primary vehicle manufacturers shall provide all parameters listed in the primary vehicle column.

— Primary vehicle manufacturers may furthermore provide additional input parameters related to the complete or completed vehicle, which can be determined already at this initial stage. In this case information on Manufacturer (P235), Manufacturer Address (P252), VIN (P238) and Date (P239) shall be provided both for the set of primary input parameters and for the set of additional input parameters.

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— Interim manufacturers shall provide input parameters related to the complete or completed vehicle which can be determined at this stage and which are under their responsibility. If a parameter which was already provided by a previous manufacturing stage is updated, the entire status of the parameter must be specified (example: if a second heat pump is added to the vehicle, the technology of both systems shall be provided). Information on Manufacturer (P235), Manufacturer Address (P252), VIN (P238) and Date (P239) and shall be provided by interim manufacturers in all cases;

— Manufactures of the completed vehicle shall provide input parameters which can be determined at this stage and which are under their responsibility. For necessary updates of parameters already provided by previous manufacturing stages, the same provisions as for interim manufacturers shall apply. Information on Manufacturer (P235), Manufacturer Address (P252), VIN (P238), Date (P239) and Corrected Actual Mass (P038) shall be provided in all cases. In order to be able to carry out the necessary simulations, the consolidated data set from all manufacturing stages must contain the entire information listed in the column for the complete vehicle or completed vehicle;

— Manufacturers related to the complete stage shall provide all input parameters. Information on Manufacturer (P235), Manufacturer Address (P252), VIN (P238) and Date (P239) shall be provided both for the primary input parameters and for the complete vehicle input parameters;

— The parameter 'VehicleDeclarationType' (P293) shall be delivered by all manufacturing stages which provide any of the parameters as listed for the complete or completed vehicle.

Table 1

Input parameters 'Vehicle/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
Manufacturer	P235	Token	[-]		X	X	X	X
Manufacturer Address	P252	Token	[-]		X	X	X	X
Model_CommercialName	P236	Token	[-]		X	X	X	X
VIN	P238	Token	[-]		X	X	X	X
Date	P239	Date Time	[-]	Date and time when input information and input data is created	X	X	X	X
Legislative Category	P251	String	[-]	Allowed values: 'N2', 'N3','M3'	X	X	X	X

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
ChassisConfiguration	P036	String	[-]	Allowed values: 'Rigid Lorry', 'Tractor', 'Van', 'Bus'	X	X	X	
AxleConfiguration	P037	String	[-]	Allowed values: '4 × 2', '4 × 2F', '6 × 2', '6 × 4', '8 × 2', '8 × 4'where '4 × 2F' refers to 4 × 2 vehicles with a driven front axle	X	X	X	
Articulated	P281	boolean		In accordance with Article 3, point (37)			X	
CorrectedActualMass	P038	Int	[kg]	In accordance with 'Corrected actual mass of the vehicle' as specified in point 2(4)	X	X		X
TechnicalPermissibleMaximumLadenMass	P041	int	[kg]	In accordance with Article 2, point (7) of Regulation (EU) No 1230/2012	X	X	X	X
IdlingSpeed	P198	int	[1/min]	In accordance with point 7.1 For PEV no input is required.	X	X	X	
RetarderType	P052	string	[-]	Allowed values: 'None', 'Losses included in Gearbox', 'Engine Retarder', 'Transmission Input Retarder', 'Transmission Output Retarder', 'Axlegear Input Retarder' 'Axlegear Input Retarder' is applicable only for powertrain architectures 'E3', 'S3', 'S-IEPC' and 'E-IEPC'	X	X	X	
RetarderRatio	P053	double, 3	[-]	Step-up ratio in accordance with table 2 of Annex VI	X	X	X	
AngledriveType	P180	string	[-]	Allowed values: 'None', 'Losses included in Gearbox', 'Separate Angledrive'	X	X	X	

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
PTOShafts GearWheels ([1])	P247	string	[-]	Allowed values: 'none', 'only the drive shaft of the PTO', 'drive shaft and/or up to 2 gear wheels', 'drive shaft and/or more than 2 gear wheels', 'only one engaged gearwheel above oil level' , 'PTO which includes 1 or more additional gearmesh(es), without disconnect clutch'	X			
PTOOther Elements ([1])	P248	string	[-]	Allowed values: 'none', 'shift claw, synchroniser, sliding gearwheel', 'multi-disc clutch', 'multi-disc clutch, oil pump'	X			
CertificationNumbe-rEngine	P261	token	[-]	Only applicable if the component is present in the vehicle	X	X	X	
CertificationNum-berGearbox	P262	token	[-]	Only applicable if the component is present in the vehicle and certified input data is provided	X	X	X	
CertificationNum-berTorqueconverter	P263	token	[-]	Only applicable if the component is present in the vehicle and certified input data is provided	X	X	X	
CertificationNumbe-rAxlegear	P264	token	[-]	Only applicable if the component is present in the vehicle and certified input data is provided	X	X	X	
CertificationNumbe-rAngledrive	P265	token	[-]	Refers to certified ADC component installed in the angle drive position. Only applicable if the component is present in the vehicle and certified input data is provided	X	X	X	

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
CertificationNum-berRetarder	P266	token	[-]	Only applicable if the component is present in the vehicle and certified input data is provided	X	X	X	
Certification NumberAirdrag	P268	token	[-]	Only applicable if certified input data is provided	X	X		X
AirdragModified-Multistage	P334	boolean	[-]	Input required for all manu-facturing stages subsequent to a first entry to the air drag component. If parameter is set to 'true' w/o providing a certified air drag component, the simu-lation tool applies standard values according to Annex VIII.				X
Certification NumberIEPC	P351	token	[-]	Only applicable if the component is present in the vehicle and certified input data is provided	X	X	X	
ZeroEmission-Vehicle	P269	boolean	[-]	As defined in Article 3, point (15)	X	X	X	
VocationalVehicle	P270	boolean	[-]	In accordance with Article 3, point (9) of Regulation (EU) 2019/1242	X			
NgTankSystem	P275	string	[-]	Allowed values: 'Com-pressed', 'Liquefied' Only relevant for vehicles with engines of fuel type 'NG PI' and 'NG CI' (P193) Where both tank systems are present on a vehicle, the system which is able to contain the higher amount of fuel energy shall be declared as input to the simulation tool.	X	X		X
Sleepercab	P276	boolean	[-]		X			

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
ClassBus	P282	string	[-]	Allowed values: 'I', 'I+II', 'A', 'II', 'II+III', 'III', 'B' in accordance with paragraph 2 of UN Regulation No. 107				X
NumberPassengers-SeatsLowerDeck	P283	int	[-]	Number of passenger seats - excluding driver and crew seats. In the case of a double deck vehicle, this parameter shall be used to declare the passenger seats from the lower deck. In the case of a single deck vehicle, this parameter shall be used to declare the number of total passenger seats.				X
NumberPassengers-StandingLowerDeck	P354	int	[-]	Number of registered standing passengers In the case of a double deck vehicle, this parameter shall be used to declare the registered standing passengers from the lower deck. In the case of a single deck vehicle, this parameter shall be used to declare the total number of registered standing passengers.				X
NumberPassengers-SeatsUpperDeck	P284	int	[-]	Number of passenger seats - excluding driver and crew seats of the upper deck in a double deck vehicle. For single deck vehicles '0' shall be provided as input.				X
NumberPassengers-StandingUpperDeck	P355	int	[-]	Number of registered standing passengers of the upper deck in a double deck vehicle. For single deck vehicles '0' shall be provided as input.				X

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
BodyworkCode	P285	int	[-]	Allowed values: 'CA', 'CB', 'CC', 'CD', 'CE', 'CF', 'CG', 'CH', 'CI', 'CJ' in accordance with point 3 of part C of Annex I to Regulation (EU) 2018/585. In the case of bus chassis with vehicle code CX, no input shall be delivered.				X
LowEntry	P286	boolean	[-]	'low entry' in accordance with point 1.2.2.3 of Annex I				X
HeightIntegratedBody	P287	int	[mm]	in accordance with point 2(5)				X
VehicleLength	P288	int	[mm]	in accordance with point 2(8)				X
VehicleWidth	P289	int	[mm]	in accordance with point 2(9)				X
EntranceHeight	P290	int	[mm]	in accordance with point 2(10)				X
DoorDriveTechnology	P291	string	[-]	Allowed values: 'pneumatic', 'electric', 'mixed'				X
Cargo volume	P292	double, 3	[m^3]	Only relevant to vehicles of chassis configuration 'van'		X		
VehicleDeclarationType	P293	string	[-]	Allowed values: 'interim', 'final'				X
VehicleTypeApprovalNumber	P352	token	[-]	Whole vehicle type approval number In the case of individual vehicle approvals, the individual vehicle approval number	X	X		X

([1]) In the event multiple PTOs are mounted to the transmission, only the component with the highest losses according to point 3.6 of Annex IX, for its combination of criteria 'PTOShaftsGearWheels' and 'PTOShaftsOtherElements', shall be declared.

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Table 2

Input parameters 'Vehicle/AxleConfiguration' per wheel axle

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
Twin Tyres	P045	boolean	[-]		X	X	X	
Axle Type	P154	String	[-]	Allowed values: 'VehicleNon-Driven', 'VehicleDriven'	X	X	X	
Steered	P195	boolean		Only active steered axles shall be declared as 'steered'	X	X	X	
Certification NumberTyre	P267	token	[-]		X	X	X	

Tables 3 and 3a provide the lists for input parameters regarding auxiliary units. The technical definitions for determining these parameters are given in Annex IX. The parameter ID is used to provide a clear reference between the parameters of Annexes III and IX.

Table 3

Input parameters 'Vehicle/Auxiliaries' for medium lorries and heavy lorries

Parameter name	Parameter ID	Type	Unit	Description/Reference
EngineCoolingFan/Technology	P181	string	[-]	Allowed values: 'Crankshaft mounted - Electronically controlled visco clutch', 'Crankshaft mounted - Bimetallic controlled visco clutch', 'Crankshaft mounted - Discrete step clutch', 'Crankshaft mounted - On/off clutch', 'Belt driven or driven via transmission - Electronically controlled visco clutch', 'Belt driven or driven via transmission - Bimetallic controlled visco clutch', 'Belt driven or driven via transmission - Discrete step clutch', 'Belt driven or driven via transmission - On/off clutch', 'Hydraulic driven - Variable displacement pump', 'Hydraulic driven - Constant displacement pump', 'Electrically driven - Electronically controlled'

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Parameter name	Parameter ID	Type	Unit	Description/Reference
SteeringPump/Technology	P182	string	[-]	Allowed values: ‘Fixed displacement’, ‘Fixed displacement with elec. control’, ‘Dual displacement’, ‘Dual displacement with elec. control’ ‘Variable displacement mech. controlled’, ‘Variable displacement elec. controlled’, ‘Electric driven pump’, ‘Full electric steering gear’ For PEV or HEV with a powertrain configuration ‘S’ or ‘S-IEPC’ in accordance with point 10.1.1 ‘Electric driven pump’ or ‘Full electric steering gear’ are the only allowed values. Separate entry for each active steered wheel axle required.
ElectricSystem/Technology	P183	string	[-]	Allowed values: ‘Standard technology’, ‘Standard technology - LED headlights, all’;
PneumaticSystem/Technology	P184	string	[-]	Allowed values: ‘Small’, ‘Small + ESS’, ‘Small + visco clutch’, ‘Small + mech. clutch’, ‘Small + ESS + AMS’, ‘Small + visco clutch + AMS’, ‘Small + mech. clutch + AMS’, ‘Medium Supply 1-stage’, ‘Medium Supply 1-stage + ESS’, ‘Medium Supply 1-stage + visco clutch ’, ‘Medium Supply 1-stage + mech. clutch’, ‘Medium Supply 1-stage + ESS + AMS’, ‘Medium Supply 1-stage + visco clutch + AMS’, ‘Medium Supply 1-stage + mech. clutch + AMS’, ‘Medium Supply 2-stage’, ‘Medium Supply 2-stage + ESS’, ‘Medium Supply 2-stage + visco clutch ’, ‘Medium Supply 2-stage + mech. clutch’, ‘Medium Supply 2-stage + ESS + AMS’, ‘Medium Supply 2-stage + visco clutch + AMS’, ‘Medium Supply 2-stage + mech. clutch + AMS’, ‘Large Supply’, ‘Large Supply + ESS’, ‘Large Supply + visco clutch’, ‘Large Supply + mech. clutch’, ‘Large Supply + ESS + AMS’, ‘Large Supply + visco clutch + AMS’, ‘Large Supply + mech. clutch + AMS’, ‘Vacuum pump’, ‘Small + elec. driven’, ‘Small + ESS + elec. driven’, ‘Medium Supply 1-stage + elec. driven’, ‘Medium Supply 1-stage + AMS + elec. driven’, ‘Medium Supply 2-stage + elec. driven’, ‘Medium Supply 2-stage + AMS + elec. driven’, ‘Large Supply + elec. driven’, ‘Large Supply + AMS + elec. driven’, ‘Vacuum pump + elec. driven’; For PEV only ‘elec. driven’ technologies are allowed values.

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Parameter name	Parameter ID	Type	Unit	Description/Reference
HVAC/Technology	P185	string	[-]	Allowed values: 'None', 'Default'

Table 3a

Input parameters 'Vehicle/Auxiliaries' for heavy buses

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
EngineCoolingFan/Technology	P181	string	[-]	Allowed values: 'Crankshaft mounted - Electronically controlled visco clutch', 'Crankshaft mounted - Bimetallic controlled visco clutch', 'Crankshaft mounted - Discrete step clutch 2 stages', 'Crankshaft mounted - Discrete step clutch 3 stages', 'Crankshaft mounted - On/off clutch', 'Belt driven or driven via transmission - Electronically controlled visco clutch', 'Belt driven or driven via transmission - Bimetallic controlled visco clutch', 'Belt driven or driven via transmission - Discrete step clutch 2 stages', 'Belt driven or driven via transmission - Discrete step clutch 3 stages', 'Belt driven or driven via transmission - On/off clutch', 'Hydraulic driven - Variable displacement pump', 'Hydraulic driven - Constant displacement pump', 'Electrically driven - Electronically controlled'	X	
SteeringPump/ Technology	P182	string	[-]	Allowed values: 'Fixed displacement', 'Fixed displacement with elec. control', 'Dual displacement', 'Dual displacement with elec. control', 'Variable displacement mech. controlled', 'Variable displacement elec. controlled', 'Electric driven pump', 'Full electric steering gear' For PEV or HEV with a powertrain configuration 'S' or 'S-IEPC' in accordance with point 10.1.1 only 'Electric driven pump' or 'Full electric steering gear' are allowed values Separate entry for each active steered wheel axle required.	X	

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
ElectricSystem/ AlternatorTechnology	P294	string	[-]	Allowed values: 'conventional', 'smart', 'no alternator' Single entry per vehicle For pure ICE vehicles only 'conventional' or 'smart' are allowed values For HEV with a powertrain configuration 'S' or 'S-IEPC' in accordance with point 10.1.1 only 'no alternator' or 'conventional' are allowed values	X	
ElectricSystem/ SmartAlternatorRatedCurrent	P295	integer	[A]	Separate entry per smart alternator	X	
ElectricSystem/ SmartAlternatorRatedVoltage	P296	Integer	[V]	Allowed values: '12', '24', '48' Separate entry per smart alternator	X	
ElectricSystem/ SmartAlternatorBatteryTechnology	P297	string	[-]	Allowed values: 'lead-acid battery – conventional', 'lead-acid battery – AGM', 'lead-acid battery – gel', 'li-ion battery - high power', 'li-ion battery - high energy' Separate entry per battery charged by smart alternator system	X	
ElectricSystem/ SmartAlternatorBatteryNominalVoltage	P298	Integer	[V]	Allowed values: '12', '24', '48' Where batteries are configured in series (e.g. two 12 V units for a 24 V system), the actual nominal voltage of the single battery units (12 V in this example) shall be provided. Separate entry per battery charged by smart alternator system	X	
ElectricSystem/ SmartAlternatorBatteryRatedCapacity	P299	Integer	[Ah]	Separate entry per battery charged by smart alternator system	X	
ElectricSystem/ SmartAlternatorCapacitorTechnology	P300	string	[-]	Allowed values: 'with DCDC converter' Separate entry per capacitor charged by smart alternator system	X	
ElectricSystem/ SmartAlternatorCapacitorRatedCapacitance	P301	integer	[F]	Separate entry per capacitor charged by smart alternator system	X	

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
ElectricSystem/ SmartAlternator-CapacitorRated-Voltage	P302	Integer	[V]	Separate entry per capacitor charged by smart alternator system	X	
ElectricSystem/ SupplyFrom-HEVPossible	P303	boolean	[-]		X	
ElectricSystem/ Interior-lightsLED	P304	boolean	[-]			X
ElectricSystem/ Dayrunning-lightsLED	P305	boolean	[-]			X
ElectricSystem/ Position-lightsLED	P306	boolean	[-]			X
ElectricSystem/ BrakelightsLED	P307	boolean	[-]			X
ElectricSystem/ HeadlightsLED	P308	boolean	[-]			X
Pneumatic-System/SizeOf-AirSupply	P309	string	[-]	Allowed values: 'Small', 'Medium Supply 1-stage', 'Medium Supply 2-stage', 'Large Supply 1-stage', 'Large Supply 2-stage', 'not applicable' For compressor drive *electrically* 'not applicable' shall be provided. For PEV no input is required.	X	
Pneumatic-System/ Compressor-Drive	P310	string	[-]	Allowed values: 'mechanically', 'electrically' For PEV, only 'electrically' is an allowed value.	X	
Pneumatic-System/Clutch	P311	string	[-]	Allowed values: 'none', 'visco', 'mechanically' For PEV no input is required.	X	
Pneumatic-System/SmartRe-generation-System	P312	boolean	[-]		X	
Pneumatic-System/Smart-Compression-System	P313	boolean	[-]	For PEV or HEV with a powertrain configuration 'S' or 'S-IEPC' in accordance with point 10.1.1 no input is required.	X	

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
Pneumatic-System/Ratio Compressor ToEngine	P314	double, 3	[-]	For compressor drive *electrically* ‘0.000’ shall be provided. For PEV no input is required.	X	
Pneumatic-System/Air suspension control	P315	string	[-]	Allowed values: ‘mechanically’, ‘electronically’	X	
Pneumatic-System/SCRReagent-Dosing	P316	boolean	[-]		X	
HVAC/System-Configuration	P317	int	[-]	Allowed values: ‘0’ to ‘10’ In the case of an incomplete HVAC system, ‘0’ shall be provided. ‘0’ is not applicable for complete or completed vehicles.		X
HVAC/ Heat-PumpTypeDri-verCompartment-Cooling	P318	string	[-]	Allowed values: ‘none’, ‘not applicable’, ‘R-744’, ‘non R-744 2-stage’, ‘non R-744 3-stage’, ‘non R-744 4-stage’, ‘non R-744 continuous’ ‘not applicable’ shall be declared for HVAC system configurations 6 and 10 due to supply from passenger heat pump		X
HVAC/ Heat-PumpTypeDri-verCompartmen-tHeating	P319	string	[-]	Allowed values: ‘none’, ‘not applicable’, ‘R-744’, ‘non R-744 2-stage’, ‘non R-744 3-stage’, ‘non R-744 4-stage’, ‘non R-744 continuous’ ‘not applicable’ shall be declared for HVAC system configurations 6 and 10 due to supply from passenger heat pump		X
HVAC/ Heat-PumpTypePass-engerCompart-mentCooling	P320	string	[-]	Allowed values: ‘none’, ‘R-744’, ‘non R-744 2-stage’, ‘non R-744 3-stage’, non R-744 4-stage’, ‘non R-744 continuous’ In the case of multiple heat pumps with different technologies for cooling the passenger compartment, the dominant technology shall be declared (e.g. according to available power or preferred usage in operation).		X
HVAC/ Heat-PumpTypePass-engerCompart-mentHeating	P321	string	[-]	Allowed values: ‘none’, ‘R-744’, ‘non R-744 2-stage’, ‘non R-744 3-stage’, non R-744 4-stage’, ‘non R-744 continuous’ In the case of multiple heat pumps with different technologies for heating the passenger compartment, the dominant technology shall be declared (e.g. according to available power or preferred usage in operation).		X
HVAC/Auxili-aryHeaterPower	P322	integer	[W]	Enter ‘0’ if no auxiliary heater is installed.		X

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
HVAC/Double glazing	P323	boolean	[-]			X
HVAC/Adjust-ableCoolant-Thermostat	P324	boolean	[-]		X	
HVAC/Adjust-ableAuxiliary-Heater	P325	boolean	[-]			X
HVAC/ EngineWasteG-asHeatExchanger	P326	boolean	[-]	For PEV no input is required.	X	
HVAC/Separ-ateAirDistribu-tionDucts	P327	boolean	[-]			X
HVAC/Water-ElectricHeater	P328	boolean	[-]	Input to be provided only for HEV and PEV		X
HVAC/AirElec-tricHeater	P329	boolean	[-]	Input to be provided only for HEV and PEV		X
HVAC/Other-Heating Tech-nology	P330	boolean	[-]	Input to be provided only for HEV and PEV		X

Table 4

Input parameters 'Vehicle/EngineTorqueLimits' per gear (optional)

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
Gear	P196	integer	[-]	only gear numbers need to be specified where vehicle related engine torque limits according to point 6 are applicable	X	X	X	
MaxTorque	P197	integer	[Nm]		X	X	X	

▼M3

Table 5

Input parameters for vehicles exempted according to Article 9

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete and completed vehicle)
Manufacturer	P235	token	[-]		X	X	X	X
ManufacturerAddress	P252	token	[-]		X	X	X	X
Model_CommercialName	P236	token	[-]		X	X	X	X
VIN	P238	token	[-]		X	X	X	X
Date	P239	date Time	[-]	Date and time when input information and input data is created	X	X	X	X
LegislativeCategory	P251	string	[-]	Allowed values: ‘N2’, ‘N3’, ‘M3’	X	X	X	X
ChassisConfiguration	P036	string	[-]	Allowed values: ‘Rigid Lorry’, ‘Tractor’, ‘Van’, ‘Bus’	X	X	X	
AxleConfiguration	P037	string	[-]	Allowed values: ‘4 × 2’, ‘4 × 2F’, ‘6 × 2’, ‘6 × 4’, ‘8 × 2’, ‘8 × 4’ where ‘4 × 2F’ refers to 4 × 2 vehicles with a driven front axle	X	X	X	
Articulated	P281	boolean		in accordance with the definition set out in Annex I to this Regulation.			X	
CorrectedActualMass	P038	int	[kg]	In accordance with ‘Corrected actual mass of the vehicle’ as specified in section 2 point (4)	X	X		X
TechnicalPermissibleMaximumLadenMass	P041	int	[kg]	In accordance with Article 2, point (7), of Regulation (EU) No 1230/2012	X	X	X	X
ZeroEmissionVehicle	P269	boolean	[-]	As defined in Article 3, point (15)	X	X	X	
Sleepercab	P276	boolean	[-]		X			

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete and completed vehicle)
ClassBus	P282	string	[-]	Allowed values: ‘I’, ‘I+II’, ‘A’, ‘II’, ‘II+III’, ‘III’, ‘B’ in accordance with paragraph 2 of UN Regulation No. 107				X
NumberPassengers-SeatsLowerDeck	P283	int	[-]	Number of passenger seats - excluding driver and crew seats. In the case of a double deck vehicle, this parameter shall be used to declare the passenger seats from the lower deck. In the case of a single deck vehicle, this parameter shall be used to declare the number of total passenger seats.				X
NumberPassengers-StandingLowerDeck	P354	int	[-]	Number of registered standing passengers In the case of a double deck vehicle, this parameter shall be used to declare the registered standing passengers from the lower deck. In the case of a single deck vehicle, this parameter shall be used to declare the total number of registered standing passengers.				X
NumberPassengers-SeatsUpperDeck	P284	int	[-]	Number of passenger seats - excluding driver and crew seats of the upper deck in a double deck vehicle. For single deck vehicles ‘0’ shall be provided as input.				X
NumberPassengers-StandingUpperDeck	P355	int	[-]	Number of registered standing passengers of the upper deck in a double deck vehicle. For single deck vehicles ‘0’ shall be provided as input.				X
BodyworkCode	P285	int	[-]	Allowed values: ‘CA’, ‘CB’, ‘CC’, ‘CD’, ‘CE’, ‘CF’, ‘CG’, ‘CH’, ‘CI’, ‘CJ’ in accordance with point 3 of part C of Annex I to Regulation (EU) 2018/585				X

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete and completed vehicle)
LowEntry	P286	boolean	[-]	'low entry' in accordance with point 1.2.2.3 of Annex I				X
HeightIntegratedBody	P287	int	[mm]	in accordance with point 2(5)				X
SumNetPower	P331	int	[W]	Maximum possible sum of positive propulsion power of all energy converters, which are linked to the vehicle drivetrain or the wheels	X	X	X	
Technology	P332	string	[-]	In accordance with Table 1 of Appendix 1. Allowed values: 'Dual-fuel vehicle Article 9 exempted', 'In-motion charging Article 9 exempted', 'Multiple powertrains Article 9 exempted', 'FCV Article 9 exempted', 'H2 ICE Article 9 exempted', 'HEV Article 9 exempted', 'PEV Article 9 exempted', 'HV Article 9 exempted'	X	X	X	

Table 6

Input parameters 'Advanced driver assistance systems'

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete and completed vehicle)
EngineStopStart	P271	boolean	[-]	In accordance with point 8.1.1 Input only to be provided for pure ICE vehicles and HEV.	X	X	X	X
EcoRollWithoutEngineStop	P272	boolean	[-]	In accordance with point 8.1.2 Input only to be provided for pure ICE vehicles.	X	X	X	X
EcoRollWithEngineStop	P273	boolean	[-]	In accordance with point 8.1.3 Input only to be provided for pure ICE vehicles.	X	X	X	X

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Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete and completed vehicle)
PredictiveCruise-Control	P274	string	[-]	In accordance with point 8.1.4, allowed values: '1,2', '1,2,3'	X	X	X	X
APTEcoRollRelease-LockupClutch	P333	boolean	[-]	Only relevant in the case of APT-S and APT-P transmissions in combination with any Eco-roll function. Set to 'true' if functionality (2) as defined in point 8.1.2 is the predominant Eco-roll mode. Input only to be provided for pure ICE vehicles.	X	X	X	X

Table 7

General input parameters for HEV and PEV

Parameter name	Parameter ID	Type	Unit	Description/Reference	Heavy lorries	Medium lorries	Heavy buses (primary vehicle)	Heavy buses (complete or completed vehicle)
ArchitectureID	P400	string	[-]	In accordance with point 10.1.3, the following values are allowed inputs: 'E2', 'E3', 'E4', 'E-IEPC', 'P1', 'P2', 'P2.5', 'P3', 'P4', 'S2', 'S3', 'S4', 'S-IEPC'	X	X	X	
OvcHev	P401	boolean	[-]	In accordance with point 2(31)	X	X	X	
MaxChargingPower	P402	Integer	[W]	The maximum charging power allowed by the vehicle for off-vehicle charging shall be declared as input to the simulation tool. Only relevant where parameter 'OvcHev' is set to 'true'.	X	X	X	

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Table 8

Input parameters per electric machine position

(Only applicable if the component is present in the vehicle)

Parameter name	Parameter ID	Type	Unit	Description/Reference
PowertrainPosition	P403	string	[-]	Position of the EM in the vehicle's powertrain according to points 10.1.2 and 10.1.3. Allowed values: '1', '2', '2.5', '3', '4', 'GEN'. Only one EM position per powertrain allowed, except for architecture 'S'. Architecture 'S' requires EM position 'GEN' and additionally one other EM position being '2', '3' or '4'. Position '1' is not allowed for architectures 'S' and 'E' Position 'GEN' is only allowed for architecture 'S'
Count	P404	integer	[-]	Number of identical electric machines at the specified EM position. In the case of parameter 'PowertrainPosition' being '4', the count shall be multiples of 2 (e.g. 2, 4, 6).
CertificationNum-berEM	P405	token	[-]	
CertificationNum-berADC	P406	token	[-]	Optional input in the case of additional single-step gear ratio (ADC) between EM shaft and connection point to vehicle's powertrain according to point 10.1.2 Not allowed where parameter 'IHPCType' is set to 'IHPC Type 1'.
P2.5GearRatios	P407	double, 3	[-]	Only applicable in the case that the parameter 'PowertrainPosition' is set to 'P2.5' Declared for each forward gear of the transmission. Declared value for gear ratio defined by either 'n_{GBX_in} / n_{EM}' in the case of EM without additional ADC or 'n_{GBX_in} / n_{ADC}' in the case of EM with additional ADC. n_{GBX_in} = rotational speed at transmission input shaft n_{EM} = rotational speed at EM output shaft n_{ADC} = rotational speed at ADC output shaft

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Table 9

Torque limitations per electric machine position (optional)

Declaration of separate dataset for each voltage level measured under ‘CertificationNumberEM’. Declaration not allowed where parameter ‘IHPCType’ is set to ‘IHPC Type 1’.

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputShaftSpeed	P408	double, 2	[1/min]	Exact same entries for rotational speed to be declared as under ‘CertificationNumberEM’ for parameter number ‘P468’ of Appendix 15 of Annex Xb.
MaxTorque	P409	double, 2	[Nm]	Maximum torque of the EM (referring to the output shaft) as function of rotational speed points declared under parameter number ‘P469’ of Appendix 15 of Annex Xb. Each value of maximum torque declared shall either be lower than 0,9 times the original value at the respective rotational speed or match exactly the original value at the respective rotational speed. The values of maximum torque declared shall not be lower than zero. Where the parameter ‘Count’ (P404) is larger than one, the maximum torque shall be declared for a single EM (as present in the component test for the EM under ‘CertificationNumberEM’).
MinTorque	P410	double, 2	[Nm]	Minimum torque of the EM (referring to the output shaft) as function of rotational speed points declared under parameter number ‘P470’ of Appendix 15 of Annex Xb. Each value of minimum torque declared shall either be higher than 0.9 times the original value at the respective rotational speed or match exactly the original value at the respective rotational speed. The values of minimum torque declared shall not be higher than zero. Where the parameter ‘Count’ (P404) is larger than one, the minimum torque shall be declared for a single EM (as present in the component test for the EM under ‘CertificationNumberEM’).

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Table 10

Input parameters per REESS

(Only applicable if the component is present in the vehicle)

Parameter name	Parameter ID	Type	Unit	Description/Reference
StringID	P411	integer	[-]	The arrangement of representative battery sub-systems in accordance with Annex Xb on vehicle level shall be declared by allocation of each battery sub-system to a specific string defined by this parameter. All specific strings are connected in parallel, all battery sub-system located in one specific parallel string are connected in series. Allowed values: ‘1’, ‘2’, ‘3’, …
CertificationNumber-REESS	P412	token	[-]	
SOCmin	P413	integer	[%]	Optional input. Only relevant in the case of REESS type ‘battery’. Parameter only effective in simulation tool where input is higher than generic value as documented in the user manual.
SOCmax	P414	integer	[%]	Optional input Only relevant in the case of REESS type ‘battery’. Parameter only effective in simulation tool where input is lower than generic value as documented in the user manual.

Table 11

Boosting limitations for parallel HEV (optional)

Only allowed where powertrain configuration in accordance with point 10.1.1 is ‘P’ or ‘IHPC Type 1’.

Parameter name	Parameter ID	Type	Unit	Description/Reference
RotationalSpeed	P415	double, 2	[1/min]	Referring to transmission input shaft speed
BoostingTorque	P416	double, 2	[Nm]	In accordance with point 10.2

4. Vehicle mass for medium rigid lorries and tractors, heavy rigid lorries and tractors

4.1 The vehicle mass used as input for the simulation tool shall be the corrected actual mass of the vehicle.

4.2 If not all the standard equipment is installed, the manufacturer shall add the mass of the following construction elements to the corrected actual mass of the vehicle:

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(a) Front underrun protection in accordance with Regulation (EU) 2019/2144 (**) of the European Parliament and of the Council

(b) Rear underrun protection in accordance with Regulation (EU) 2019/2144

(c) Lateral protection in accordance with Regulation (EU) 2019/2144

(d) Fifth wheel in accordance with Regulation (EU) 2019/2144

4.3 The mass of the construction elements referred to in point 4.2 shall be the following:

For vehicles of groups 1s, 1, 2 and 3 as set out in Annex I, Table 1, and for vehicle groups 51 and 53 as set out in Annex I, Table 2.

(a) Front underride protection	45 kg
(b) Rear underride protection	40 kg
(c) Lateral protection	8,5 kg/m × wheel base [m] – 2,5 kg

For vehicles of groups 4, 5, 9 to 12 and 16 as set out in Annex I, Table 1.

(a) Front under-ride protection	50 kg
(b) Rear under-ride protection	45 kg
(c) Lateral protection	14 kg/m × wheel base [m] – 17 kg
(d) Fifth wheel	210 kg

5. Hydraulically and mechanically driven axles

In the case of vehicles equipped with:

(a) a hydraulically driven axles, the axle shall be treated as a non-drivable one and the manufacturer shall not take it into consideration for establishing an axle configuration of a vehicle;

(b) a mechanically driven axles, the axle shall be treated as a drivable one and the manufacturer shall take it into consideration for establishing an axle configuration of a vehicle;

6. Gear dependent engine torque limits and gear disabling

6.1. Gear dependent engine torque limits

For the highest 50 % of the gears (e.g. for gears 7 to 12 of a 12-gear transmission) the vehicle manufacturer may declare a gear dependent maximum engine torque limit which is not higher than 95 % of the maximum engine torque.

6.2 Gear disabling

For the highest 2 gears (e.g. gear 5 and 6 for a 6-gear transmission) the vehicle manufacturer may declare a complete disabling of gears by providing 0 Nm as gear specific torque limit in the input to the simulation tool.

6.3 Verification requirements

Gear dependent engine torque limits in accordance with point 6.1 and gear disabling in accordance with point 6.2 are subject to verification in the verification testing procedure (VTP) as laid out in Annex Xa, point 6.1.1.1 c).

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7. Vehicle specific engine idling speed

7.1. The engine idling speed has to be declared for each individual vehicle with an ICE. This declared vehicle engine idling shall be equal or higher than specified in the engine input data approval.

8. Advanced driver assistance systems

8.1 The following types of advanced driver assistance systems, which are primarily aiming for reduction of fuel consumption and CO_2 emissions, shall be declared in the input to the simulation tool:

8.1.1 Engine stop-start during vehicle stops: system which automatically shuts down and restarts the internal combustion engine during vehicle stops to reduce engine idling time. For automatic engine shut down the maximum time delay after the vehicle stop shall be not longer than 3 seconds.

8.1.2 Eco-roll without engine stop-start: system which automatically decouples the internal combustion engine from the drivetrain during specific downhill driving conditions with low negative gradients. The system shall be active at least at all cruise control set speeds above 60 km/h. Any system to be declared in the input information to the simulation tool shall cover either one or both of the following functionalities:

Functionality (1)'

The combustion engine is de-coupled from the drivetrain, and engine operates at idle speed. In the case of APT-transmissions, the torque converter lock-up clutch is closed.

Functionality (2) Torque converter lock-up clutch open

The torque converter lock-up clutch is open during Eco-roll mode. This allows the engine to operate in coast mode at lower engine speeds and reduces or even eliminates fuel injection. Functionality (2) is relevant only for APT-transmissions.

8.1.3 Eco-roll with engine stop-start: system which automatically decouples the internal combustion engine from the drivetrain during specific downhill driving conditions with low negative slopes. During these phases the internal combustion engine is shut down after a short time delay and keeps shut down during the main share of the eco-roll phase. The system shall be active at least at all cruise control set speeds of above 60 km/h.

8.1.4 Predictive cruise control (PCC): systems which optimise the usage of potential energy during a driving cycle based on an available preview of road gradient data and the use of a GPS system. A PCC system declared in the input to the simulation tool shall have a gradient preview distance longer than 1 000 meters and cover all following functionalities:

(1) Crest coasting

Approaching a crest the vehicle velocity is reduced before the point where the vehicle starts accelerating by gravity alone compared to the set speed of the cruise control so that the braking during the following downhill phase can be reduced.

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(2) Acceleration without engine power

During downhill driving with a low vehicle velocity and a high negative slope the vehicle acceleration is performed without any engine power usage so that the downhill braking can be reduced.

(3) Dip coasting

During downhill driving when the vehicle is braking at the overspeed velocity, PCC increases the overspeed for a short period of time to end the downhill event with a higher vehicle velocity. Overspeed is a higher vehicle speed than the set speed of the cruise control system.

A PCC system can be declared as input to the simulation tool if either the functionalities set out in points (1) and (2) or points (1), (2) and (3) are covered.

8.2 The eleven combinations of the advanced driver assistance systems as set out in Table 12 are input parameters into the simulation tool. Combinations 2 to 11 shall not be declared for SMT transmissions. Combinations No 3, 6, 9 and 11 shall not be declared in the case of APT transmissions.

Table 12

Combinations of advanced driver assistance systems as input parameters into the simulation tool

Combination no	Engine stop-start during vehicle stops	Eco-roll without engine stop-start	Eco-roll with engine stop-start	Predictive cruise control
1	yes	no	no	no
2	no	yes	no	no
3	no	no	yes	no
4	no	no	no	yes
5	yes	yes	no	no
6	yes	no	yes	no
7	yes	no	no	yes
8	no	yes	no	yes
9	no	no	yes	yes
10	yes	yes	no	yes
11	yes	no	yes	yes

8.3 Any advanced driver assistance system declared in the input into the simulation tool shall by default be set to fuel economy mode after each key-off/key-on cycle.

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8.4 If an advanced driver assistance system is declared in the input into the simulation tool, it shall be possible to verify the presence of such a system based on real world driving and the system definitions as set out in point 8.1. If a certain combination of systems is declared, also the interaction of functionalities (e.g. predictive cruise control plus eco-roll with engine stop-start) shall be demonstrated. In the verification procedure it shall be taken into consideration, that the systems need certain boundary conditions to be ‘active’ (e.g. engine at operation temperature for engine stop-start, certain vehicle speed ranges for PCC, certain ratios of road gradients with vehicle mass for eco-roll). The vehicle manufacturer needs to submit a functional description of boundary conditions when the systems are ‘inactive’ or their efficiency is reduced. The approval authority may request the technical justifications of these boundary conditions from the applicant for approval and assess them for compliance.

9. Cargo volume

9.1. For vehicles of chassis configuration ‘van’ the cargo volume shall be calculated by the following equation:

$$Cargo\ volume = \frac{(L_{C,floor} + L_{C})}{2} \cdot \frac{(W_{C,max} + W_{C,wheelhouse})}{2} \cdot \frac{(H_{C,max} + H_{C,rearwheel})}{2} [m^3]$$

where the dimensions shall be determined in accordance with Table 13 and Figure 3.

Table 13

Definitions related to cargo volume for medium lorries of type van

Formula symbol	Dimension	Definition
$L_{C,floor}$	Cargo length at floor	— longitudinal distance from the most rearward point of the last seating row or the partition wall to the foremost point of the closed rear compartment projected to the zero Y-plane — measured at the height of the cargo floor surface
L_C	Cargo length	— longitudinal distance from the X-plane tangent to the most rearward point on the seatback including head restraints of the last seating row or the partition wall to the foremost X-plane tangent to the closed rear compartment i.e. the tailgate or rear doors or any other limiting surface — measured at the height of the most rearward point of the last seating row or the partition wall
$W_{C,max}$	Maximum cargo width	— maximum lateral distance of the cargo compartment — measured between the cargo floor and 70 mm above the floor — measurement excludes the transitional arc, local protrusions, depressions or pockets if present

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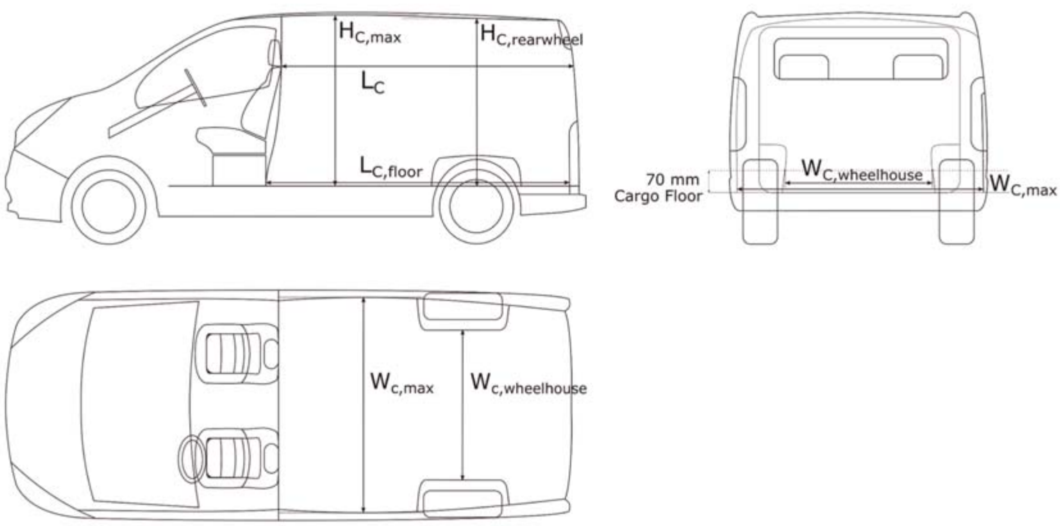
Formula symbol	Dimension	Definition
$W_{C,wheelhouse}$	Cargo width at wheelhouse	— minimum lateral distance between the limiting interferences (pass-through) of the wheelhouses — measured between the cargo floor and 70 mm above the floor — measurement excludes the transitional arc, local protrusions, depressions or pockets if present
$H_{C,max}$	Maximum cargo height	— Maximum vertical distance from the cargo floor to the headlining or other limiting surface — Measured behind the last seating row or partition wall at the vehicle centreline
$H_{C,rearwheel}$	Cargo height at rear wheel	— vertical distance from the top of the cargo floor to the headlining or the limiting surface — measured at the rear wheel X coordinate at the vehicle centreline

Figure 3

Definition of cargo volume for medium lorries



10. HEV and PEV

The following provisions shall apply only in the case of HEV and PEV.

10.1 Definition of vehicle's powertrain architecture

10.1.1 Definition of powertrain configuration

The configuration of the vehicle's powertrain shall be determined in accordance with the following definitions:

In the case of a HEV:

(a) 'P' in the case of a parallel HEV

(b) 'S' in the case of a serial HEV

(c) 'S-IEPC' in the case an IEPC component is present in the vehicle

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(d) 'IHPC Type 1' in the case the parameter 'IHPCType' of the electric machine component is set to 'IHPC Type 1'

In the case of a PEV:

(a) 'E' in the case an EM component is present in the vehicle

(b) 'E-IEPC' in the case an IEPC component is present in the vehicle

10.1.2 Definition of positions of EMs in the vehicle's powertrain

Where the configuration of the vehicle's powertrain in accordance with point 10.1.1 is 'P', 'S' or 'E', the position of the EM installed in the vehicle's powertrain shall be determined in accordance with the definitions set out in Table 14.

Table 14

Possible positions of EMs in the vehicle's powertrain

Position index of EM	Powertrain configuration in accordance with point 10.1.1	Transmission type in accordance with Table 1 in Appendix 12 of Annex VI	Definition / Requirements [1]	Further explanations
1	P	AMT, APT-S, APT-P	Connected to the powertrain upstream of the clutch (in the case of AMT) or upstream of the torque converter input shaft (in the case of APT-S or APT-P). The EM is connected to the crankshaft of the ICE directly or via a mechanical connection type (e.g. belt).	Distinction of P0: EMs which can as a matter of principle not contribute to the propulsion of the vehicle (i.e. alternators) are handled in the input to auxiliary systems (see Table 3 of this Annex for lorries, Table 3a of this Annex for buses and Annex IX). However, EMs at this position which can in principle contribute to the propulsion of the vehicle but for which the declared maximum torque in accordance with Table 9 of this Annex is set to zero shall be declared as 'P1'.
2	P	AMT	The electric machine is connected to the powertrain downstream of the clutch and upstream of the transmission input shaft.	
2	E, S	AMT, APT-N, APT-S, APT-P	The electric machine is connected to the powertrain upstream of the transmission input shaft (in the case of AMT or APT-N) or upstream of the torque converter input shaft (in the case of APT-S, APT-P).	

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Position index of EM	Powertrain configuration in accordance with point 10.1.1	Transmission type in accordance with Table 1 in Appendix 12 of Annex VI	Definition / Requirements [1]	Further explanations
2,5	P	AMT, APT-S, APT-P	The electric machine is connected to the powertrain downstream of the clutch (in the case of AMT) or downstream of the torque converter input shaft (in the case of APT-S or APT-P) and upstream of the transmission output shaft.	The EM is connected to a specific shaft inside the transmission (e.g. layshaft). A specific transmission ratio for each mechanical gear in the transmission according to Table 8 shall be provided.
3	P	AMT, APT-S, APT-P	The electric machine is connected to the powertrain downstream of the transmission output shaft and upstream of the axle.	
3	E, S	n.a.	The electric machine is connected to the powertrain upstream of the axle.	
4	P	AMT, APT-S, APT-P	The electric machine is connected to the powertrain downstream of the axle.	
4	E, S	n.a.	The electric machine is connected to the wheel hub and the same arrangement is installed twice in symmetrical application (i.e. one on the left and one on the right side of the vehicle at the same wheel position in logitudinal direction).	
GEN	S	n.a.	The electric machine is mechanically connected to an ICE but under no operational circumstances mechanically connected to the wheels of the vehicle.	

(1) The term EM as used here includes an additional ADC component, if present.

10.1.3 Definition of powertrain architecture ID

The input value for the powertrain architecture ID required in accordance with Table 7 shall be determined based on the powertrain configuration in accordance with point 10.1.1 and the position of the EM in the vehicle's powertrain in accordance with point 10.1.2 (if applicable) from the valid combinations of inputs into the simulation tool listed in Table 15.

In the case of the powertrain configuration in accordance with point 10.1.1 being 'IHPC Type 1' the following provisions shall apply:

(a) The powertrain architecture ID 'P2' shall be declared in accordance with Table 7 and the powertrain component data as indicated in Table 15 for 'P2' shall be the input to the simulation

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tool with separate component data for the EM and the transmission determined in accordance with point 4.4.3 of Annex Xb.

(b) The component data for the EM in accordance with subpoint (a) shall be provided to the simulation tool with the parameter 'PowertrainPosition' in accordance with Table 8 set to '2'.

Table 15

Valid inputs of powertrain architecture into the simulation tool

Powertrain type	Powertrain configuration	Architecture ID for VECTO input	Powertrain component present in vehicle								Comments
			ICE	EM position GEN	EM position 1	EM position 2	transmission	EM position 3	axle	EM position 4	
PEV	E	E2	no	no	no	yes	yes	no	yes	no	
		E3	no	no	no	no	no	yes	yes	no	
		E4	no	no	no	no	no	no	no	yes	
	IEPC	E-IEPC	no	no	no	no	no	no	(1)	no	
HEV	P	P1	yes	no	yes	no	yes	no	yes	no	
		P2	yes	no	no	yes	yes	no	yes	no	(2)
		P2.5	yes	no	no	yes	yes	no	yes	no	(3)
		P3	yes	no	no	no	yes	yes	yes	no	(4)
		P4	yes	no	no	no	yes	no	yes	yes	
	S	S2	yes	yes	no	yes	yes	no	yes	no	
		S3	yes	yes	no	no	no	yes	yes	no	
		S4	yes	yes	no	no	no	no	no	yes	
		S-IEPC	yes	yes	no	no	no	no	(1)	no	

(1) 'Yes' (i.e. axle component present) only in the case that both parameters 'DifferentialIncluded' and 'DesignTypeWheelMotor' are set to 'false'
(2) Not applicable for transmission types APT-S and APT-P
(3) Where the EM is connected to a specific shaft inside the transmission (e.g. layshaft) in accordance with the definition set out in Table 8
(4) Not applicable for front wheel driven vehicles

10.2 Definition of boosting limitation for parallel HEV

The vehicle manufacturer may declare limitations of the total propulsion torque of the whole powertrain referring to the transmission input shaft for a parallel HEV in order to restrict the boosting capabilities of the vehicle.

The declaration of such limitations is allowed only in the case that the powertrain configuration in accordance with point 10.1.1 is 'P' or 'IHPC Type 1'.

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The limitations are declared as additional torque allowed on top of the ICE full load curve dependent on the rotational speed of the transmission input shaft. Linear interpolation is performed in the simulation tool to determine the applicable additional torque between the declared values at two specific rotational speeds. In the rotational speed range from 0 to engine idling speed (in accordance with point 7.1) the full load torque available from the ICE equals only the ICE full load torque at engine idling speed due to the modelling of the clutch behaviour during vehicle starts.

Where such a limitation is declared, values for the additional torque shall be declared at least at a rotational speed of 0 and at the maximum rotational speed of the ICE full load curve. Any arbitrary number of values may be declared in between the range of zero and the maximum rotational speed of the ICE full load curve. Declared values lower than zero shall not be allowed for the additional torque.

The vehicle manufacturer may declare such limitations which match exactly the ICE full load curve by declaring values of 0 Nm for the additional torque.

10.3 Engine stop-start functionality for HEVs

Where the vehicle is equipped with an engine stop-start functionality in accordance with point 8.1.1 considering the boundary conditions in point 8.4, the input parameter P271 in accordance with Table 6 shall be set to true.

11. Transfer of results of the simulation tool to other vehicles

11.1. Results of the simulation tool may be transferred to other vehicles as provided for in Article 9(6), provided that all of the following conditions are met:

(a) input data and input information is completely identical with exception of VIN (P238) and Date element (P239). In the case of simulations for primary heavy buses, additional input data and input information relevant for the interim vehicle and available already at the initial stage may differ, but special measures have to be taken in this case;

(b) the version of the simulation tool is identical.

11.2. For the transfer of results the following result files shall be considered:

(a) medium and heavy lorries: manufacturer's records file and customer information file

(b) primary heavy buses: manufacturer's records file and vehicle information file

(c) complete or completed heavy buses: manufacturer's records file, customer information file and vehicle information file

11.3. To carry out the transfer of results the files as mentioned in 10.2. shall be modified by replacing the data elements as set out in the subpoints with updated information. Modifications are allowed only for data elements related to the current stage of completion.

11.3.1 Manufacturer's records file

(a) VIN (Annex IV, Part I, point 1.1.3)

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(b) Date when the output file was created (Annex IV, Part I, point 3.2)

11.3.2 Customer information file

(a) VIN (Annex IV, Part II, point 1.1.1)

(b) Date when the output file was created (Annex IV, Part II, point 3.2)

11.3.3 Vehicle information file

11.3.3.1. In the case of a primary heavy bus:

(a) VIN (Annex IV, Part III, point 1.1)

(b) Date when the output file was created (Annex IV, Part III, point 1.3.2)

11.3.3.2. Where a manufacturer of a primary heavy bus provides data going beyond the primary vehicle requirements and which differs between original vehicle and transferred vehicle, the related data elements in the vehicle information file shall be updated accordingly.

11.3.3.3. In the case of a complete or completed heavy bus:

(a) VIN (Annex IV, Part III, point 2.1)

(b) Date when the output file was created (Annex IV, Part III, point 2.2.2)

11.3.4 After the modifications as described above the signature elements as set out below shall be updated.

11.3.4.1. Lorries:

(a) Manufacturer's records file: Annex IV, Part I, points 3.6. and 3.7

(b) Customer information file: Annex IV, Part II, points 3.3 and 3.4

11.3.4.2. Primary heavy buses:

(a) Manufacturer's records file: Annex IV, Part I, points 3.3 and 3.4

(b) Vehicle information file: Annex IV, Part III, points 1.4.1 and 1.4.2

11.3.4.3. Primary heavy buses where additionally input data for the interim vehicle has been provided:

(a) Manufacturer's records file: Annex IV, Part I, points 3.3 and 3.4

(b) Vehicle information file: Annex IV, Part III, points 1.4.1, 1.4.2 and 2.3.1

11.3.4.4. Complete or completed heavy buses

(a) Manufacturer's records file: Annex IV, Part I, points 3.6 and 3.7

(b) Vehicle information file: Annex IV, Part III, point 2.3.1

11.4. Where CO_2 emissions and fuel consumption cannot be determined for the original vehicle due to a malfunction of the simulation tool, the same measures shall apply to the vehicles with transferred results.

11.5. If the approach to transfer results to other vehicles as laid down in this paragraph is applied by a manufacturer, the related process shall be demonstrated to the approval authority as part of granting the process licence.

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Appendix 1

Vehicle technologies for which the obligations laid down in Article 9(1), first subparagraph, do not apply, as provided in that subparagraph

Table 1

Vehicle technology category	Criteria for exemption	Input parameter value in accordance with Table 5 of this Annex
Fuel cell vehicle	The vehicle is either a fuel cell vehicle or a fuel cell hybrid vehicle in accordance with point 2 (12) or (13) of this Annex.	'FCV Article 9 exempted'
ICE operated with hydrogen	The vehicle is equipped with an ICE that is capable of running on hydrogen fuel.	'H2 ICE Article 9 exempted'
Dual-fuel	Dual-fuel vehicles of types 1B, 2B and 3B as defined in Article 2(53), 2(55) and 2(56) of Regulation (EU) No 582/2011	'Dual-fuel vehicle Article 9 exempted'
HEV	Vehicles shall be exempted where at least one of the following criteria apply: — The vehicle is equipped with multiple EMs which are not placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex. — The vehicle is equipped with multiple EMs which are placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex but do not have exactly identical specifications (i.e. the same component certificate). This criterion shall not apply where the vehicle is equipped with an IHPC Type 1. — The vehicle has a powertrain architecture other than P1 to P4, S2 to S4, S-IEPC in accordance with point 10.1.3 of this Annex or other than IHPC Type 1.	'HEV Article 9 exempted'
PEV	Vehicles shall be exempted where at least one of the following criteria apply: — The vehicle is equipped with multiple EMs which are not placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex. — The vehicle is equipped with multiple EMs which are placed at the same connection point in the drivetrain in accordance with point 10.1.2 of this Annex but do not have exactly identical specifications (i.e. the same component certificate). This criterion shall not apply where the vehicle is equipped with an IEPC. — The vehicle has a powertrain architecture other than E2 to E4 or E-IEPC in accordance with point 10.1.3 of this Annex.	'PEV Article 9 exempted'

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Vehicle technology category	Criteria for exemption	Input parameter value in accordance with Table 5 of this Annex
Multiple permanently mechanically independent powertrains	The vehicle is equipped with more than one powertrain where each powertrain is propelling different wheel axle(s) of the vehicle and where different powertrains can under no circumstances be mechanically connected. In this regard hydraulically driven axles shall, in accordance with point 5(a) of this Annex, be treated as non-driven axles and shall thus not be counted as an independent powertrain.	'Multiple powertrains Article 9 exempted'
In-motion charging	The vehicle is equipped with means for conductive or inductive supply of electric energy to the vehicle in motion, which is at least partly directly used for vehicle propulsion and optionally for charging a REESS.	'In-motion charging Article 9 exempted'
Non-electric hybrid vehicles	The vehicle is a HV but not a HEV in accordance with point 2 (26) and (27) of this Annex.	'HV Article 9 exempted'

(*) Commission Regulation (EU) No 1230/2012 of 12 December 2012 implementing Regulation (EC) No 661/2009 of the European Parliament and of the Council with regard to type-approval requirements for masses and dimensions of motor vehicles and their trailers and amending Directive 2007/46/EC of the European Parliament and of the Council (OJ L 353, 21.12.2012, p. 31).

(**) Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users, amending Regulation (EU) 2018/858 of the European Parliament and of the Council and repealing Regulations (EC) No 78/2009, (EC) No 79/2009 and (EC) No 661/2009 of the European Parliament and of the Council and Commission Regulations (EC) No 631/2009, (EU) No 406/2010, (EU) No 672/2010, (EU) No 1003/2010, (EU) No 1005/2010, (EU) No 1008/2010, (EU) No 1009/2010, (EU) No 19/2011, (EU) No 109/2011, (EU) No 458/2011, (EU) No 65/2012, (EU) No 130/2012, (EU) No 347/2012, (EU) No 351/2012, (EU) No 1230/2012 and (EU) 2015/166 (OJ L 325, 16.12.2019, p. 1).

▼**M3**

ANNEX IV

MODEL OF THE OUTPUT FILES OF THE SIMULATION TOOL

1. Introduction

This Annex describes the models of the manufacturer's records file (MRF), the customer information file (CIF) and the vehicle information file (VIF).

2. Definitions

(1) 'actual charge depleting range': The range that can be driven in charge depleting mode based on the usable amount of REESS energy, without any interim charging.

(2) 'equivalent all electric range': The part of the actual charge depleting range that can be attributed to the use of electric energy from the REESS, i.e. without any energy provided by the non-electric propulsion energy storage system.

(3) 'zero CO_2 emissions range': The range that can be attributed to energy provided by propulsion energy storage systems considered with zero CO_2 impact.

3. Model of the output files

PART I

Vehicle CO_2 emissions and fuel consumption – Manufacturer's records file

The manufacturer's records file shall be produced by the simulation tool and shall at least contain the following information, if applicable for the specific vehicle or manufacturing step:

1. Vehicle, component, separate technical unit and systems data

1.1. Vehicle data

1.1.1. Name and address of manufacturer (s) ....

1.1.2. Vehicle model / Commercial Name ....

1.1.3. Vehicle identification number (VIN) ....

1.1.4. Vehicle category (N2, N3, M3) ....

1.1.5. Axle configuration ....

1.1.6. Technically Permissible Maximum Laden Mass (t) ....

1.1.7. Vehicle group in accordance with Annex I ....

1.1.7a. Vehicle (sub-)group for CO_2 ....

1.1.8. Corrected actual mass (kg) ....

1.1.9. Vocational vehicle (yes/no) ....

1.1.10. Zero emission heavy-duty vehicle (yes/no) ....

1.1.11. Hybrid electric heavy-duty vehicle (yes/no) ....

1.1.12. Dual-fuel vehicle (yes/no) ....

▼M3

1.1.13. Sleeper cab (yes/no) ....

1.1.14. HEV architecture (e.g. P1, P2) ....

1.1.15. PEV architecture (e.g. E2, E3) ....

1.1.16. Off-vehicle charging capability (yes/no) ....

1.1.17. –

1.1.18. Off-vehicle charging maximum power (kW) ....

1.1.19. Vehicle technology exempted according to Article 9 ....

1.1.20. Class of bus (e.g. I, I+II etc.) ....

1.1.21. Number passengers upper deck ....

1.1.22. Number passengers lower deck ....

1.1.23. Code for bodywork (e.g. CA, CB) ....

1.1.24. Low Entry (yes/no) ....

1.1.25. Height integrated body (mm) ....

1.1.26. Vehicle length (mm) ....

1.1.27. Vehicle width (mm) ....

1.1.28. Door drive technology (pneumatic, electric, mixed) ....

1.1.29. Tank system in the case of natural gas (compressed, liquified) ..

1.1.30. Sum net power (only for Article 9 exempted) (kW) ....

1.2. Main engine specifications

1.2.1. Engine model ....

1.2.2. Engine certification number ....

1.2.3. Engine rated power (kW) ....

1.2.4. Engine idling speed (1/min) ....

1.2.5. Engine rated speed (1/min) ....

1.2.6. Engine capacity (ltr) ....

1.2.7. Fuel type (Diesel CI/CNG PI/LNG PI) ....

1.2.8. Hash of the engine input data and input information ....

1.2.9. Waste heat recovery system (yes/no) ....

1.2.10. Waste heat recovery type(s) (mechanical/electrical) ....

▼**M3**

1.3. Main transmission specifications

1.3.1. Transmission model ....

1.3.2. Transmission certification number ....

1.3.3. Main option used for generation of loss maps (Option1/Option2/ Option3/Standard values) ....

1.3.4. Transmission type (SMT, AMT, APT-S, APT-P, APT-N) ....

1.3.5. No. of gears ....

1.3.6. Transmission ratio final gear ....

1.3.7. Retarder type ....

1.3.8. Power take off (yes/no) ....

1.3.9. Hash of the transmission input data and input information ....

1.4. Retarder specifications

1.4.1. Retarder model ....

1.4.2. Retarder certification number ....

1.4.3. Certification option used for generation of a loss map (standard values/measurement) ....

1.4.4. Hash of the other torque transferring components input data and input information ....

1.5. Torque converter specification

1.5.1. Torque converter model ....

1.5.2. Torque converter certification number ....

1.5.3. Certification option used for generation of a loss map (standard values/measurement) ....

1.5.4. Hash of the torque converter input data and input information ..

1.6. Angle drive specifications

1.6.1. Angle drive model ....

1.6.2. Angle drive certification number ....

1.6.3. Certification option used for generation of a loss map (standard values/measurement) ....

1.6.4. Angle drive ratio ....

1.6.5. Hash of the additional drivetrain components input data and input information ....

1.7. Axle specifications

1.7.1. Axle model ....

1.7.2. Axle certification number ....

1.7.3. Certification option used for generation of a loss map (standard values/measurement) ....

1.7.4. Axle type (e.g. single reduction axle) ....

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1.7.5. Axle ratio ....

1.7.6. Hash of the axle input data and input information ....

1.8. Aerodynamics

1.8.1. Model ....

1.8.2. Certification option used for generation of CdxA (standard values/ measurement) ....

1.8.3. CdxA Certification number (if applicable) ....

1.8.4. CdxA value ....

1.8.5. Hash of the air drag input data and input information ....

1.9. Main tyre specifications

1.9.1. Tyre dimension axle 1 ....

1.9.2. Tyre certification number axle 1 ....

1.9.3. Specific RRC of all tyres on axle 1 ....

1.9.3a. Hash of the tyre input data and input information axle 1 ....

1.9.4. Tyre dimension axle 2 ....

1.9.5. Twin axle (yes/no) axle 2 ....

1.9.6. Tyre certification number axle 2 ....

1.9.7. Specific RRC of all tyres on axle 2 ....

1.9.7a. Hash of the tyre input data and input information axle 2 ....

1.9.8. Tyre dimension axle 3 ....

1.9.9. Twin axle (yes/no) axle 3 ....

1.9.10. Tyre certification number axle 3 ....

1.9.11. Specific RRC of all tyres on axle 3 ....

1.9.11a. Hash of the tyre input data and input information axle 3 ....

1.9.12. Tyre dimension axle 4 ....

1.9.13. Twin axle (yes/no) axle 4 ....

1.9.14. Tyre certification number axle 4 ....

1.9.15. Specific RRC of all tyres on axle 4 ....

1.9.16. Hash of the tyre input data and input information axle 4 ....

▼M3

1.10. Auxiliary specifications

1.10.1. Engine cooling fan technology ....

1.10.2. Steering pump technology ....

1.10.3. Electric system

1.10.3.1. Alternator technology (conventional, smart, no alternator) ....

1.10.3.2. Max alternator power (smart alternator) (kW) ....

1.10.3.3. Electric storage capacity (smart alternator) (kWh) ....

1.10.3.4. Day running lights LED (yes/no) ....

1.10.3.5. Head lights LED (yes/no) ....

1.10.3.6. Position lights LED (yes/no) ....

1.10.3.7. Brake lights LED (yes/no) ....

1.10.3.8. Interior lights LED (yes/no) ....

1.10.4. Pneumatic system

1.10.4.1. Technology ....

1.10.4.2. Compressor ratio ....

1.10.4.3. Smart compression system ....

1.10.4.4. Smart regeneration system ....

1.10.4.5. Air suspension control ....

1.10.4.6. Reagent dosing (exhaust after-treatment) ....

1.10.5. HVAC system

1.10.5.1. System configuration number ....

1.10.5.2. Heat pump type cooling driver compartment ....

1.10.5.3. Heat pump mode heating driver compartment ....

1.10.5.4. Heat pump type cooling passenger compartment ....

1.10.5.5. Heat pump mode heating passenger compartment ....

1.10.5.6. Auxiliary heater power (kW) ....

1.10.5.7. Double glasing (yes/no) ....

1.10.5.8. Adjustable coolant thermostat (yes/no) ....

1.10.5.9. Adjustable auxiliary heater ....

▼M3

1.10.5.10. Engine waste gas heat exchanger (yes/no) ....

1.10.5.11. Separate air distribution ducts (yes/no) ....

1.10.5.12. Water electric heater

1.10.5.13. Air electric heater

1.10.5.14. Other heating technology

1.11. Engine torque limitations

1.11.1. Engine torque limit at gear 1 (% of max engine torque) ....

1.11.2. Engine torque limit at gear 2 (% of max engine torque) ....

1.11.3. Engine torque limit at gear 3 (% of max engine torque) ....

1.11.4. Engine torque limit at gear .... (% of max engine torque)

1.12. Advanced driver assistance systems (ADAS)

1.12.1. Engine stop-start during vehicle stops (yes/no) ....

1.12.2. Eco-roll without engine stop-start (yes/no) ....

1.12.3. Eco-roll with engine stop-start (yes/no) ....

1.12.4. Predictive cruise control (yes/no) ....

1.13. Electric machine system(s) specifications

1.13.1 Model ....

1.13.2. Certification number

1.13.3 Type (PSM, ESM, IM, SRM) ....

1.13.4. Position (GEN 1, 2, 3, 4) ....

1.13.5. –

1.13.6. Count at position ....

1.13.7. Rated power (kW) ....

1.13.8. Maximum continuous power (kW) ....

1.13.9. Certification option for generation of electric power consumption map ....

1.13.10. Hash of the input data and input information ....

1.13.11. ADC model ....

1.13.12. ADC certification number ....

1.13.13. Certification option used for generation of an ADC loss map (standard values/measurement) ....

1.13.14. ADC ratio ....

1.13.15. Hash of the additional driveline components' input data and input information ....

▼M3

1.14. Integrated electric powertrain system (IEPC) specifications

1.14.1 Model ....

1.14.2. Certification number ....

1.14.3. Rated power (kW) ....

1.14.4. Maximum continuous power (kW) ....

1.14.5. Number of gears ....

1.14.6. Lowest total transmission ratio (highest gear times axle ratio if applicable) ....

1.14.7. Differential included (yes/no) ....

1.14.8. Certification option for generation of electric power consumption map ....

1.14.9. Hash of the input data and input information ....

1.15. Rechargeable Energy Storage Systems specifications

1.15.1 Model ....

1.15.2. Certification number ....

1.15.3. Nominal voltage (V) ....

1.15.4. Total storage capacity (kWh) ....

1.15.5. Total usable capacity in simulation (kWh) ....

1.15.6. Certification option for electric system losses ....

1.15.7. Hash of the input data and input information ....

1.15.8. StringID (-) ....

2. Mission profile and loading dependent values

2.1. Simulation parameters (for each mission profile and loading combination, for OVC-HEVs additionally for charge depleting, charge sustaining mode and weighted)

2.1.1. Mission profile ....

2.1.2. Load (as defined in the simulation tool) (kg) ....

2.1.2a. Passenger count ....

2.1.3. Total vehicle mass in simulation (kg) ....

2.1.4. OVC mode (charge depleting, charge sustaining, weighted) ....

2.2. Vehicle driving performance and information for simulation quality check

2.2.1. Average speed (km/h) ....

2.2.2. Minimum instantaneous speed (km/h) ....

2.2.3. Maximum instantaneous speed (km/h) ....

2.2.4. Maximum deceleration (m/s^2) ....

2.2.5. Maximum acceleration (m/s^2) ....

2.2.6. Full load percentage of driving time ....

▼**M3**

2.2.7. Total number of gear shifts ....

2.2.8. Total driven distance (km) ....

2.3. Fuel and energy consumption (per fuel type and electric energy) and CO_2 results (total)

2.3.1. Fuel consumption (g/km) ....

2.3.2. Fuel consumption (g/t-km) ....

2.3.3. Fuel consumption (g/p-km) ....

2.3.4. Fuel consumption (g/m^3-km) ....

2.3.5. Fuel consumption (l/100km) ....

2.3.6. Fuel consumption (l/t-km) ....

2.3.7. Fuel consumption (l/p-km) ....

2.3.8. Fuel consumption (l/m^3-km) ....

2.3.9. Energy consumption (MJ/km, kWh/km) ....

2.3.10. Energy consumption (MJ/t-km, kWh/t-km) ....

2.3.11. Energy consumption (MJ/p-km, kWh/p-km) ....

2.3.12. Energy consumption (MJ/m^3-km, kWh/m^3-km) ....

2.3.13. CO_2 (g/km) ....

2.3.14. CO_2 (g/t-km) ....

2.3.15. CO_2 (g/p-km) ....

2.3.16. CO_2 (g/m^3-km) ....

2.4. Electric and zero emission ranges

2.4.1. Actual charge depleting range (km) ....

2.4.2. Equivalent all electric range (km) ....

2.4.3. Zero CO_2 emission range (km) ....

3. Software information

3.1. Simulation tool version (X.X.X) ....

3.2. Date and time of the simulation ....

3.3. Cryptographic hash simulation tool input information and input data of the primary vehicle (if applicable) ....

3.4. Cryptographic hash of the manufacturer's record file of the primary vehicle (if applicable) ....

3.5. Cryptographic hash of the vehicle information file as produced by the simulation tool (if applicable) ....

3.6. Cryptographic hash of the simulation tool input information and input data ....

3.7. Cryptographic hash of the manufacturer's records file ....

▼M3

PART II

Vehicle CO_2 emissions and fuel consumption - Customer information file

The customer information file shall be produced by the simulation tool and shall at least contain the following information, if applicable for the specific vehicle or certification step:

1. Vehicle, component, separate technical unit and systems data

1.1. Vehicle data

1.1.1. Vehicle identification number (VIN) ....

1.1.2. Vehicle category (N_2, N_3, M_3) ....

1.1.3. Axle configuration ....

1.1.4. Technically Permissible Maximum Laden Mass (t) ....

1.1.5. Vehicle group in accordance with Annex I ....

1.1.5a. Vehicle (sub-)group for CO_2 ....

1.1.6. Name and address(es) of manufacturer(s) ....

1.1.7. Model ....

1.1.8. Corrected actual mass (kg) ....

1.1.9. Vocational vehicle (yes/no) ....

1.1.10. Zero emission heavy-duty vehicle (yes/no) ....

1.1.11 Hybrid electric heavy-duty vehicle (yes/no) ....

1.1.12 Dual-fuel vehicle (yes/no) ....

1.1.12a. Waste Heat recovery (yes/no) ....

1.1.13. Sleeper cab (yes/no) ....

1.1.14. HEV architecture (e.g. P1, P2) ....

1.1.15. PEV architecture (e.g. E2, E3) ....

1.1.16. Off-vehicle charging capability (yes/no) ....

1.1.17. –

1.1.18. Off-vehicle charging maximum power (kW) ....

1.1.19. Vehicle technology exempted from Article 9 ....

1.1.20. Class of bus (e.g. I, I+II etc.) ....

1.1.21. Total number of registered passengers ....

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1.2. Component, separate technical unit and systems data

1.2.1. Engine rated power (kW) ....

1.2.2. Engine capacity (ltr) ....

1.2.3. Fuel type (Diesel CI/CNG PI/LNG PI) ....

1.2.4. Transmission values (measured/standard) ....

1.2.5. Transmission type (SMT, AMT, APT, none) ....

1.2.6. No. of gears ....

1.2.7. Retarder (yes/no) ....

1.2.8. Axle ratio ....

1.2.9. Average rolling resistance coefficient (RRC) of all tyres of the motor vehicle: ....

1.2.10a. Tyre dimension for each axle of the motor vehicle ....

1.2.10b. Fuel efficiency class(es) of the tyres in accordance with Regulation (EU) 2020/740 for each axle of the motor vehicle ....

1.2.10c. Tyre certification number for each axle of the motor vehicle .....

1.2.11. Engine stop-start during vehicle stops (yes/no) ....

1.2.12. Eco-roll without engine stop-start (yes/no) ....

1.2.13. Eco-roll with engine stop-start (yes/no) ....

1.2.14. Predictive cruise control (yes/no) ....

1.2.15 Electric machine system(s) total rated propulsion power (kW) ....

1.2.16 Electric machine system total maximum continuous propulsion power (kW) ....

1.2.17 REESS total storage capacity (kWh) ....

1.2.18 REESS useable storage capacity in simulation (kWh) ....

1.3. Auxiliary configuration

1.3.1. Steering pump technology ....

1.3.2. Electric system

1.3.2.1 Alternator technology (conventional, smart, no alternator) ....

1.3.2.2 Max alternator power (smart alternator) (kW) ....

1.3.2.3 Electric storage capacity (smart alternator) (kWh) ....

1.3.3. Pneumatic system

1.3.3.1 Smart compression system ....

1.3.3.2 Smart regeneration system ....

▼**M3**

1.3.4. HVAC system

1.3.4.1 System configuration ....

1.3.4.2 Auxiliary heater power (kW) ....

1.3.4.3 Double glazing (yes/no) ....

2. CO_2 emissions and fuel consumption of the vehicle (for each mission profile and loading combination, for OVC-HEVs additionally for charge depleting, charge sustaining mode and weighted)

2.1. Simulation parameters

2.1.1 Mission profile ....

2.1.2 Payload (kg) ....

2.1.3 Passenger information

2.1.3.1 Number of passengers in simulation .... (-)

2.1.3.2 Mass of passengers in simulation .... (kg)

2.1.4 Total vehicle mass in simulation (kg) ....

2.1.5. OVC mode (charge depleting, charge sustaining, weighted) ....

2.2. Average speed (km/h) ....

2.3. Fuel and energy consumption results (per fuel type and electric energy)

2.3.1. Fuel consumption (g/km) ....

2.3.2. Fuel consumption (g/t-km) ....

2.3.3. Fuel consumption (g/p-km) ....

2.3.4. Fuel consumption (g/m^3-km) ....

2.3.5. Fuel consumption (l/100km) ....

2.3.6. Fuel consumption (l/t-km) ....

2.3.7. Fuel consumption (l/p-km) ....

2.3.8. Fuel consumption (l/m^3-km) ....

2.3.9. Energy consumption (MJ/km, kWh/km) ....

2.3.10. Energy consumption (MJ/t-km, kWh/t-km) ....

2.3.11. Energy consumption (MJ/p-km, kWh/p-km) ....

2.3.12. Energy consumption (MJ/m^3-km, kWh/m^3-km) ....

▼M3

2.4. CO_2 results (for each mission profile and loading combination)

2.4.1. CO_2 (g/km) ....

2.4.2. CO_2 (g/t-km) ....

2.4.3. CO_2 (g/p-km) ....

2.4.5. CO_2 (g/m^3-km) ....

2.5. Electric Ranges

2.5.1. Actual charge depleting range (km) ....

2.5.2. Equivalent all electric range (km) ....

2.5.3. Zero CO_2 emission range (km) ....

2.6. Weighted results

2.6.1. Specific CO_2 emissions (gCO_2/t-km) ....

2.6.2. Specific electric energy consumption (kWh/t-km) ....

2.6.3. Average payload value (t) ....

2.6.4. Specific CO_2 emissions (gCO_2/p-km) ....

2.6.5. Specific electric energy consumption (kWh/p-km) ....

2.6.6. Average passenger count (p) ....

2.6.7. Actual charge depleting range (km) ....

2.6.8. Equivalent all electric range (km) ....

2.6.9. Zero CO_2 emission range (km) ....

3. Software information

3.1. Simulation tool version ....

3.2. Date and time of the simulation ....

3.3. Cryptographic hash of the simulation tool input information and input data of the primary vehicle (if applicable) ....

3.4. Cryptographic hash of the manufacturer's records file of the primary vehicle (if applicable) ....

3.5. Cryptographic hash of the vehicle simulation tool input information and input data ....

3.6. Cryptographic hash of the manufacturer's records file ....

3.7. Cryptographic hash of the customer information file ....

▼M3

PART III

Vehicle CO_2 emissions and fuel consumption – Vehicle information file for heavy buses

The vehicle information file shall be produced in the case of heavy buses to transfer the relevant input data, input information and simulation results to subsequent certification steps following the method as described in point 2 of Annex I.

The vehicle information file shall at least contain the following content:

1. In the case of a primary vehicle:

1.1. Input data and input information as set out in Annex III for the primary vehicle except: engine fuel map; engine correction factors WHTC_Urban, WHTC_Rural, WHTC_Motorway, BFColdHot, CFRegPer; torque converter characteristics; loss maps for transmission, retarder, angle drive and axle; electric power consumption map(s) for electric motor systems and IEPC; electric loss parameters for REESS

1.2. For each mission profile and loading condition:

1.2.1. Total vehicle mass in simulation (kg) ....

1.2.2. Number of passengers in simulation (-) ....

1.2.3. Energy consumption (MJ/km) ....

1.3. Software information

1.3.1. Simulation tool version ....

1.3.2. Date and time of the simulation ....

1.4. Cryptographic hashes

1.4.1. Cryptographic hash of the manufacturers records file of the primary vehicle ....

1.4.2. Cryptographic hash of the vehicle information file ....

2. For each interim, complete or completed vehicle

2.1. Input data and input information as set out for the complete or completed vehicle in Annex III and which was provided by the particular manufacturer

2.2. Software information

2.2.1. Simulation tool version ....

2.2.2. Date and time of the simulation ....

2.3. Cryptographic hashes

2.3.1. Cryptographic hash of the vehicle information file ....

▼B

ANNEX V

VERIFYING ENGINE DATA

1. Introduction

The engine test procedure described in this Annex shall produce input data relating to engines for the simulation tool.

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2. Definitions

For the purposes of this Annex the definitions set out in UN Regulation No. 49 ([1]) and, in addition to these, the following definitions shall apply:

▼B

(1) ‘engine CO_2-family’ means a manufacturer's grouping of engines, as defined in paragraph 1 of Appendix 3;

(2) ‘CO_2-parent engine’ means an engine selected from an engine CO_2-family as specified in Appendix 3;

(3) ‘NCV’ means net calorific value of a fuel as specified in paragraph 3.2;

(4) ‘specific mass emissions’ means the total mass emissions divided by the total engine work over a defined period expressed in g/kWh;

(5) ‘specific fuel consumption’ means the total fuel consumption divided by the total engine work over a defined period expressed in g/kWh;

(6) ‘FCMC’ means fuel consumption mapping cycle;

(7) ‘Full load’ means the delivered engine torque/power at a certain engine speed when the engine is operated at maximum operator demand;

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(8) ‘Waste Heat Recovery system’ or ‘WHR system’ means all devices converting energy from the exhaust gas or from operating fluids in engine cooling systems into electrical or mechanical energy;

(9) ‘WHR system with no external output’ or ‘WHR_no_ext’ means a WHR system which generates mechanical energy and is mechanically connected to the engine crankshaft in order to feed its generated energy directly back to the engine crankshaft;

(10) ‘WHR system with external mechanical output’ or ‘WHR_mech’ means a WHR system which generates mechanical energy and feeds it to other elements in the vehicle’s drivetrain than the engine or to a rechargeable storage;

(11) ‘WHR system with external electrical output’ or ‘WHR_elec’ means a WHR system which generates electrical energy and feeds it to the vehicle’s electric circuit or to a rechargeable storage;

([1]) Regulation No. 49 of the Economic Commission for Europe of the United Nations (UN/ECE) – Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines and positive ignition engines for use in vehicles (OJ L 171, 24.6.2013, p. 1).

▼M3

(12) 'P_WHR_net' means the net power generated by a WHR system in accordance with point 3.1.6;

(13) 'E_WHR_net' means the net energy generated by a WHR system over a certain amount of time determined by integrating P_WHR_net;

The definitions set out in paragraphs 3.1.5 and 3.1.6 of Annex 4 to UN Regulation No. 49 shall not apply.

▼B

3. General requirements

►M3 The calibration laboratory facilities shall comply with the requirements of either IATF 16949, ISO 9000 series or ISO/IEC 17025 ◄. All laboratory reference measurement equipment, used for calibration and/or verification, shall be traceable to national or international standards.

Engines shall be grouped into engine CO_2-families defined in accordance with Appendix 3. Paragraph 4.1 explains which testruns shall be performed for the purpose of certification of one specific engine CO_2-family.

3.1 Test conditions

All testruns performed for the purpose of certification of one specific engine CO_2-family defined in accordance with Appendix 3 to this Annex shall be conducted on the same physical engine and without any changes to the setup of the engine dynamometer and the engine system, apart from the exceptions defined in paragraph 4.2 and Appendix 3.

3.1.1 Laboratory test conditions

The tests shall be conducted under ambient conditions meeting the following conditions over the whole testrun:

▼M3

(1) The parameter 'fa' describing the laboratory test conditions, determined in accordance with paragraph 6.1 of Annex 4 to UN Regulation No. 49, shall be within the following limits: $0,96 \leq fa \leq 1,04$.

(2) The absolute temperature (Ta) of the engine intake air expressed in Kelvin, determined in accordance with paragraph 6.1 of Annex 4 to UN Regulation No. 49 shall be within the following limits: $283\ K \leq Ta \leq 303\ K$.

(3) The atmospheric pressure expressed in kPa, determined in accordance with paragraph 6.1 of Annex 4 to UN Regulation No. 49 shall be within the following limits: $90\ kPa \leq ps \leq 102\ kPa$.

▼B

If tests are performed in test cells that are able to simulate barometric conditions other than those existing in the atmosphere at the specific test site, the applicable f_a value shall be determined with the simulated values of atmospheric pressure by the conditioning system. The same reference value for the simulated atmospheric pressure shall be used for the intake air and exhaust path and all other relevant engine systems. The actual value of the simulated atmospheric pressure for the intake air and exhaust path and all other relevant engine systems shall be within the limits specified in subpoint (3).

▼B

In cases where the ambient pressure in the atmosphere at the specific test site exceeds the upper limit of 102 kPa, tests in accordance with this Annex may still be performed. In this case tests shall be performed with the specific ambient air pressure in the atmosphere.

In cases where the test cell has the ability to control temperature, pressure and/or humidity of engine intake air independent of the atmospheric conditions the same settings for those parameters shall be used for all testruns performed for the purpose of certification of one specific engine CO_2-family defined in accordance with Appendix 3 to this Annex.

▼M3

3.1.2 Engine installation

The test engine shall be installed in accordance with paragraphs 6.3 to 6.6 of Annex 4 to UN Regulation No. 49.

If auxiliaries/equipment necessary for operating the engine system are not installed as required in accordance with paragraph 6.3 of Annex 4 to UN Regulation No. 49, all measured engine torque values shall be corrected for the power required for driving these components for the purpose of this Annex in accordance with paragraph 6.3 of Annex 4 to UN Regulation No. 49.

Such corrections of engine torque and power values shall be performed if the sum of absolute values of additional or missing engine torque required for driving these engine components in a specific engine operation point exceeds the torque tolerances defined in accordance with paragraph 4.3.5.5 (1) subparagraph (b). Where such an engine component is operated in an intermittent manner, the engine torque values for driving the respective component shall be determined as average value over an appropriate period, reflecting the actual operating mode based on good engineering judgement and in agreement with the approval authority.

For the purpose of determining whether such a correction is required or not, as well as for deriving the actual values to perform the correction, the power consumption of the following engine components, resulting in the engine torque required for driving these engine components, shall be determined in accordance with Appendix 5 of this Annex:

(1) fan;

(2) electrically powered auxiliaries/equipment necessary for operating the engine system

▼B

3.1.3 Crankcase emissions

In the case of a closed crankcase, the manufacturer shall ensure that the engine's ventilation system does not permit the emission of any crankcase gases into the atmosphere. ►M3 If the crankcase is of an open type, the emissions shall be measured and added to the tailpipe emissions, following the provisions set out in paragraph 6.10 of Annex 4 to UN Regulation No. 49. ◄

3.1.4 Engines with charge air-cooling

During all testruns the charge air cooling system used on the test bed shall be operated under conditions which are representative for in-vehicle application at reference ambient conditions. The reference ambient conditions are defined as 293 K for air temperature and 101,3 kPa for pressure.

▼M3

The laboratory charge air cooling for tests according to this Regulation should comply with the provisions specified in paragraph 6.2 of Annex 4 to UN Regulation No. 49.

▼B

3.1.5 Engine cooling system

(1) During all testruns the engine cooling system used on the test bed shall be operated under conditions which are representative for in-vehicle application at reference ambient conditions. The reference ambient conditions are defined as 293 K for air temperature and 101,3 kPa for pressure.

(2) The engine cooling system should be equipped with thermostats according to the manufacturer specification for vehicle installation. If either a non-operational thermostat is installed or no thermostat is used, subpoint (3) shall apply. The setting of the cooling system shall be performed in accordance with subpoint (4).

(3) If no thermostat is used or a non-operational thermostat is installed, the test bed system shall reflect the behavior of the thermostat under all test conditions. The setting of the cooling system shall be performed in accordance with subpoint (4).

▼M1

(4) The engine coolant flow rate (or alternatively the pressure difference across the engine side of the heat exchanger) and the engine coolant temperature shall be set to a value representative for in-vehicle application at reference ambient conditions when the engine is operated at rated speed and full load with the engine thermostat in fully open position. This setting defines the coolant reference temperature. For all testruns performed for the purpose of certification of one specific engine within one engine CO_2-family, the cooling system setting shall not be changed, neither on the engine side nor on the test bed side of the cooling system. The temperature of the test bed side cooling medium shall be kept reasonably constant by good engineering judgement. The cooling medium on the test bed side of the heat exchanger shall not exceed the nominal thermostat opening temperatur downstream of the heat exchanger.

▼B

(5) For all testruns performed for the purpose of certification of one specific engine within one engine CO_2-family the engine coolant temperature shall be maintained between the nominal value of the thermostat opening temperature declared by the manufacturer and the coolant reference temperature in accordance with subpoint (4) as soon as the engine coolant has reached the declared thermostat opening temperature after engine cold start.

(6) ►M3 For the WHTC coldstart test performed in accordance with paragraph 4.3.3, the specific initial conditions are specified in paragraphs 7.6.1 and 7.6.2 of Annex 4 to UN Regulation No. 49. ◄ If simulation of the thermostat behaviour in accordance with subpoint (3) is applied, there shall be no coolant flow across the heat exchanger as long as the engine coolant has not reached the declared nominal thermostat opening temperature after cold start.

▼M3

3.1.6 Set up of WHR systems

The following requirements shall apply where a WHR system is present on the engine.

3.1.6.1 For parameters listed in 3.1.6.2. installation on the test bed shall not result in better performance of the WHR system related to generated power by the system as compared to the specifications for in-use installation in a vehicle. All other WHR related systems used on the test bed shall be operated under conditions which are representative for in-vehicle application at reference ambient conditions. The WHR related reference ambient conditions are defined as 293 K for air temperature and 101.3 kPa for pressure.

3.1.6.2 The engine test setup shall reflect the worst-case condition with regards to temperature and energy content transferred from excess energy to the WHR system. The following parameters have to be set to reflect the worst-case condition and need to be recorded in accordance with Figure 1a and have to be reported in the information document drawn up in accordance with the model set out in Appendix 2 of this Annex:

(a) The distance between the last after treatment system and the heat exchangers for evaporation of working fluids of WHR systems (boilers), measured in the direction downstream of the engine (L_{EW}), shall be equal to or greater than the maximum distance ($Lmax_{EW}$) specified by the manufacturer of the WHR system for in-use installation in vehicles.

(b) In the case of WHR systems with turbine(s) in the exhaust gas flow, the distance between the engine outlet and the entry into the turbine (L_{ET}) shall be equal or larger than the maximum distance ($Lmax_{ET}$) specified by the manufacturer of the WHR system for in-use installation in vehicles.

(c) For WHR systems operated in a cyclic process using a working fluid:

(i) The total pipe length between evaporator and expander (L_{HE}) shall be equal or longer than defined by the manufacturer as maximum distance for in-use installation in vehicles ($Lmax_{HE}$);

(ii) The total pipe length between expander and condenser (L_{EC}) shall be equal or shorter than defined by the manufacturer as maximum distance for in-use installation in vehicles ($Lmax_{EC}$);

(iii) The total pipe length between condenser and evaporator (L_{CE}) shall be equal or shorter than defined by the manufacturer as maximum distance for in-use installation in vehicles ($Lmax_{CE}$);

(iv) The pressure p_{cond} of the working fluid before entering the condenser shall correspond to the in-use application in vehicles at reference ambient conditions but shall in any case not be lower than the ambient pressure in the test cell minus 5 kPa, unless the manufacturer demonstrates that a lower pressure can be maintained over vehicle lifetime in-use;

(v) The cooling power on the test bed for cooling the WHR condenser shall be limited to a maximum value of $P_{cool} = k \times (t_{cond} - 20\ °C)$.

▼M3

P_{cool} shall be measured either on the working fluid side or on the test bed coolant side. Where t_{cond} is defined as the condensation temperature (in °C) of the fluid at p_{cond}.

$$k = f_0 + f_1 \times V_c.$$

With: V_c is the engine displacement in litres (rounded to 2 places to the right of the decimal point)

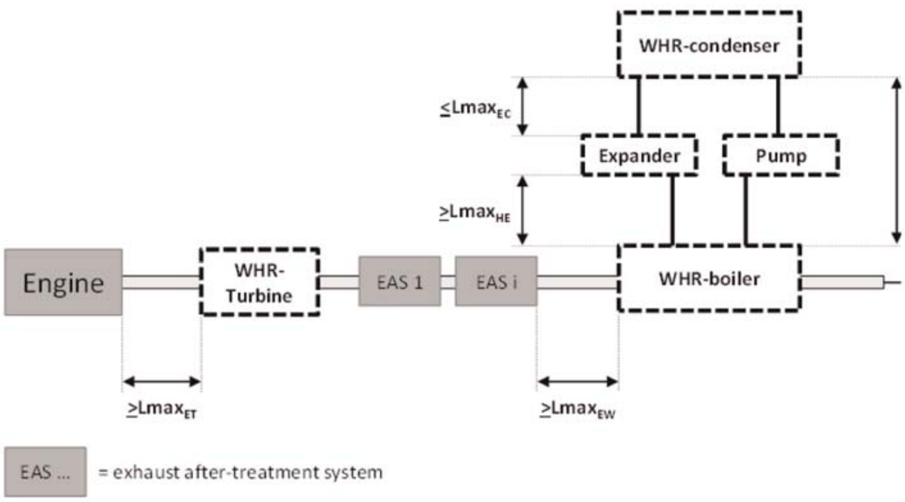
$$f_0 = 0{,}6 \text{ kW/K}$$

$$f_1 = 0{,}05 \text{ kW/(K*l)};$$

(vi) For cooling the WHR condenser on the test bed either liquid-cooling or air-cooling is allowed. In the case of an air-cooled condenser, the system shall be cooled with the same fan (if applicable) as installed on the vehicle and under the reference ambient conditions stated in subpoint 3.1.6.1. above. In the case of an air-cooled condenser, the limitation for cooling power stated in subpoint (v) above shall apply, where the actual cooling power shall be measured on the working fluid side of the heat condenser. Where the power for driving such a fan is provided from an external power source, the respective actual power consumed by the fan shall be considered as power delivered to the WHR system when determining the net power in accordance with subpoint (f) below.

Figure 1a

Definitions of minimum and maximum distances for WHR components for engine tests



(d) Other WHR systems taking heat energy from the exhaust or cooling system shall be set up in accordance with the provisions in subpoint (c). The "evaporator" in subpoint (c) refers to the heat exchanger to transfer excess heat to the WHR device. The "expander" in subpoint (c) refers to the device converting the energy.

(e) All pipe diameters of WHR systems shall be equal or smaller than the diameters defined for in-use.

(f) For WHR_mech systems the net mechanical power shall be measured at the rotational engine speed expected at 60 km/h. If different transmission ratios are expected to be used, the rotational speed shall be calculated with the average over these transmission ratios. The mechanical or electrical power generated by a WHR system shall be measured with measurement equipment meeting the respective requirements set out in Table 2.

▼M3

(i) The net electric power is the sum of the electric power delivered by the WHR system to an external power sink or rechargeable storage, minus the electric power delivered to the WHR system from an external power source or rechargeable storage. The net electric power shall be measured as DC power, i.e. after the conversion from AC to DC.

(ii) The net mechanical power is the sum of the mechanical power delivered by the WHR system to an external power sink or rechargeable storage (if applicable), minus the mechanical power delivered to the WHR system from an external power source or rechargeable storage.

(iii) All transmission systems for electrical and mechanical power necessary for the vehicle in-use shall be set up for the measurement during the engine testing (e.g. cardan shafts or belt drives for mechanical connection, AC/DC converters and DC/DC voltage transformers). If a transmission system applied in the vehicle is not part of the test set up the net electrical or mechanical power measured shall be decreased accordingly by multiplication by a generic efficiency factor for each separate transmission system. The following generic efficiencies shall be applied for transmission systems not included in the set up:

Table 1

Generic efficiencies of transmission systems for WHR power

Type of transmission	Efficiency factor for WHR power
Gear stage	0,96
Belt drive	0,92
Chain drive	0,94
DC/DC converter	0,95

▼B

3.2 Fuels

The respective reference fuel for the engine systems under test shall be selected from the fuel types listed in Table 1. The fuel properties of the reference fuels listed in Table 1 shall be those specified in Annex IX to Commission Regulation (EU) No 582/2011.

To ensure that the same fuel is used for all testruns performed for the purpose of certification of one specific engine CO_2-family no refill of the tank or switch to another tank supplying the engine system shall occur. Exceptionally a refill or switch may be allowed if it can be ensured that the replacement fuel has exactly the same properties as the fuel used before (same production batch).

▼B

The NCV for the fuel used shall be determined by two separate measurements in accordance with the respective standards for each fuel type defined in Table 1. The two separate measurements shall be performed by two different labs independent from the manufacturer applying for certification. The lab performing the measurements shall comply with the requirements of ISO/IEC 17025. The approval authority shall ensure that the fuel sample used for determination of the NCV is taken from the batch of fuel used for all testruns.

If the two separate values for the NCV are deviating by more than 440 Joule per gram fuel, the values determined shall be void and the measurement campaign shall be repeated.

▼M1

The mean value of the two separate NCV that are not deviating by more than 440 Joule per gram fuel shall be documented in MJ/kg rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

▼B

For gas fuels the standards for determining the NCV according to Table 1 contain the calculation of the calorific value based on the fuel composition. The gas fuel composition for determining the NCV shall be taken from the analysis of the reference gas fuel batch used for the certification tests. For the determination of the gas fuel composition used for determining the NCV only one single analysis by a lab independent from the manufacturer applying for certification shall be performed. For gas fuels the NCV shall be determined based on this single analysis instead of a mean value of two separate measurements.

▼M1

For gas fuels, switches between fuel tanks of different production batches are allowed exceptionally; in that case, the NCV of each used fuel batch should be calculated and the highest value should be documented.

▼B

Table 1

Reference fuels for testing

Fuel type / engine type	Reference fuel type	Standard used for determination of NCV
Diesel / CI	B7	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
Ethanol / CI	ED95	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
Petrol / PI	E10	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
Ethanol / PI	E85	at least ASTM D240 or DIN 59100-1 (ASTM D4809 is recommended)
LPG / PI	LPG Fuel B	ASTM 3588 or DIN 51612
▼M1 ►M3 Natural gas / PI or Natural Gas / CI ◄	G_{25} or G_R	ISO 6976 or ASTM 3588

▼M3

3.2.1 For dual-fuel engines the respective reference fuels for the engine systems under test shall be selected from the fuel types listed in Table 1. One of the two reference fuels shall always be B7 and the other reference fuel shall be G_{25}, G_R or LPG Fuel B.

The basic provisions stated in point 3.2 shall be applied for each of the two selected fuels separately.

▼B

3.3 Lubricants

►M3 The lubricating oil for all test runs performed in accordance with this Annex shall be a commercially available oil with unrestricted manufacturer approval under normal in-service conditions as defined in paragraph 4.2 of Annex 8 to UN Regulation No. 49. ◄ Lubricants for which the usage is restricted to certain special operation conditions of the engine system or having an unusually short oil change interval shall not be used for the purpose of testruns in accordance with this Annex. The commercially available oil shall not be modified by any means and no additives shall be added.

All testruns performed for the purpose of certification of the CO_2 emissions and fuel consumption related properties of one specific engine CO_2-family shall be performed with the same type of lubricating oil.

3.4 Fuel flow measurement system

All fuel flows consumed by the whole engine system shall be captured by the fuel flow measurement system. Additional fuel flows not directly supplied to the combustion process in the engine cylinders shall be included in the fuel flow signal for all testruns performed. Additional fuel injectors (e.g. cold start devices) not necessary for the operation of the engine system shall be disconnected from the fuel supply line during all testruns performed.

▼M3

3.4.1 Special requirements for dual-fuel engines

For dual-fuel engines the fuel flow in accordance with point 3.4 shall be measured for each of the two selected fuels separately.

▼B

3.5 Measurement equipment specifications

▼M3

The measurement equipment shall meet the requirements of paragraph 9 of Annex 4 to UN Regulation No. 49.

Notwithstanding the requirements defined in paragraph 9 of Annex 4 to UN Regulation No. 49, the measurement systems listed in Table 2 shall meet the limits defined in Table 2.

▼B

Table 2

Requirements of measurement systems

	Linearity					
Measurement system	Intercept $\mid x_{min} \times (a_1 - 1) + a_0 \mid$	Slope a_1	Standard error of estimate SEE	Coefficient of determination r^2	Accuracy (1)	Rise time (2)
Engine speed	≤ 0,2 % max calibration (3)	0,999 - 1,001	≤ 0,1 % max calibration (3)	≥ 0,9985	0,2 % of reading or 0,1 % of max. calibration (3) of speed whichever is larger	≤ 1 s

▼B

	Linearity					
Measurement system	Intercept $\mid x_{min} \times (a_1 - 1) + a_0 \mid$	Slope a_1	Standard error of estimate SEE	Coefficient of determination r^2	Accuracy (1)	Rise time (2)
Engine torque	≤ 0,5 % max calibration (3)	0,995 - 1,005	≤ 0,5 % max calibration (3)	≥ 0,995	0,6 % of reading or 0,3 % of max. calibration (3) of torque whichever is larger	≤ 1 s
Fuel mass flow for liquid fuels	≤ 0,5 % max calibration (3)	0,995 - 1,005	≤ 0,5 % max calibration (3)	≥ 0,995	0,6 % of reading or 0,3 % of max. calibration (3) of flow whichever is larger	≤ 2 s
Fuel mass flow for gaseous fuels	≤ 1 % max calibration (3)	0,99 - 1,01	≤ 1 % max calibration (3)	≥ 0,995	1 % of reading or 0,5 % of max. calibration (3) of flow whichever is larger	≤ 2 s
Electrical Power	≤ 1 % max calibration (3)	0,98 - 1,02	≤ 2 % max calibration (3)	≥ 0,990	n.a.	≤ 1 s
Current	≤ 1 % max calibration (3)	0,98 - 1,02	≤ 2 % max calibration (3)	≥ 0,990	n.a.	≤ 1 s
Voltage	≤ 1 % max calibration (3)	0,98 - 1,02	≤ 2 % max calibration (3)	≥ 0,990	n.a.	≤ 1 s
▼M3 **Temperature relevant for WHR system**	≤ 1,5 % max calibration (3)	0,98 - 1,02	≤ 2 % max calibration (3)	≥ 0,980	n.a.	≤ 10 s
Pressure relevant for WHR system	≤ 1,5 % max calibration(3)	0,98 - 1,02	≤ 2 % max calibration (3)	≥ 0,980	n.a.	≤ 3 s
Electrical power relevant for WHR system	≤ 2 % max calibration (3)	0,97 - 1,03	≤ 4 % max calibration (3)	≥ 0,980	n.a.	≤ 1 s
Mechanical power relevant for WHR system	≤ 1 % max calibration (3)	0,995 - 1,005	≤ 1,0 % max calibration (3)	≥ 0,99	1,0 % of reading or 0,5 % of max. calibration (3) of power whichever is larger	≤ 1 s

▼B

(1) 'Accuracy' means the deviation of the analyzer reading from a reference value which is traceable to a national or international standard.
(2) 'Rise time' means the difference in time between the 10 percent and 90 percent response of the final analyzer reading ($t_{90} - t_{10}$).
(3) The 'max calibration' values shall be 1,1 times the maximum predicted value expected during all testruns for the respective measurement system.

▼M3

In the case of dual-fuel engines, the 'max calibration' value applicable for the measurement system for fuel mass flow for both liquid and gaseous fuels shall be defined in accordance with the following provisions:

(1) The fuel type for which the fuel mass flow shall be determined by the measurement system subject to verification of the requirements defined in Table 2 shall be the primary fuel. The other fuel type shall be the secondary fuel.

(2) The maximum predicted value expected during all test runs for the secondary fuel shall be converted to the maximum predicted value expected during all test runs for the primary fuel by application of the following equation:

$$mf^{*}_{mp,seco} = mf_{mp,seco} \times NCV_{seco} / NCV_{prim}$$

where:

$mf^{*}_{mp,seco}$ = maximum predicted massflow value of the secondary fuel converted to the primary fuel

$mf_{mp,seco}$ = maximum predicted massflow value of the secondary fuel

NCV_{prim} = NCV of the primary fuel determined in accordance with point 3,2 [MJ/kg]

NCV_{seco} = NCV of the secondary fuel determined in accordance with point 3,2 [MJ/kg]

(3) The maximum predicted overall value, $mf_{mp,overall}$, expected during all test runs shall be determined by application of the following equation:

$$mf_{mp,overall} = mf_{mp,prim} + mf^{*}_{mp,seco}$$

where:

$mf_{mp,prim}$ = maximum predicted massflow value of the primary fuel

$mf^{*}_{mp,seco}$ = maximum predicted massflow value of the secondary fuel converted to the primary fuel

(4) The 'max calibration' values shall be 1.1 times the maximum predicted overall value, $mf_{mp,overall}$, determined in accordance with subpoint (3) above.

'x_{min}', used for calculation of the intercept value in Table 2, shall be 0,9 times the minimum predicted value expected during all test runs for the respective measurement system.

The signal delivery rate of the measurement systems listed in Table 2, except for the fuel mass flow measurement system, shall be at least 5 Hz (≥ 10 Hz recommended). The signal delivery rate of the fuel mass flow measurement system shall be at least 2 Hz.

▼B

All measurement data shall be recorded with a sample rate of at least 5 Hz (≥ 10 Hz recommended).

3.5.1 Measurement equipment verification

A verification of the demanded requirements defined in Table 2 shall be performed for each measurement system. At least 10 reference values between x_{min} and the 'max calibration' value defined in accordance with paragraph 3.5 shall be introduced to the measurement system and the response of the measurement system shall be recorded as measured value.

For the linearity verification the measured values shall be compared to the reference values by using a least squares linear regression in accordance with paragraph A.3.2 of Appendix 3 to Annex 4 to ►M3 UN Regulation No. 49 ◄.

4. Testing procedure

All measurement data shall be determined in accordance with Annex 4 to ►M3 UN Regulation No. 49 ◄, unless stated otherwise in this Annex.

4.1 Overview of testruns to be performed

Table 3 gives an overview of all testruns to be performed for the purpose of certification of one specific engine CO_2-family defined in accordance with Appendix 3.

The fuel consumption mapping cycle in accordance with paragraph 4.3.5 and the recording of the engine motoring curve in accordance with paragraph 4.3.2 shall be omitted for all other engines except the CO_2-parent engine of the engine CO_2-family.

In the case that upon request of the manufacturer the provisions defined in Article 15(5) of this Regulation are applied, the fuel consumption mapping cycle in accordance with paragraph 4.3.5 and the recording of the engine motoring curve in accordance with paragraph 4.3.2 shall be performed additionally for that specific engine.

Table 3

Overview of testruns to be performed

Testrun	Reference to paragraph	Required to be run for CO_2-parent engine	Required to be run for other engines within CO_2-family
Engine full load curve	4.3.1	yes	yes
Engine motoring curve	4.3.2	yes	no
WHTC test	4.3.3	yes	yes
WHSC test	4.3.4	yes	yes
Fuel consumption mapping cycle	4.3.5	yes	no

▼B

4.2 Allowed changes to the engine system

Changing of the target value for the engine idle speed controller to a lower value in the electronic control unit of the engine shall be allowed for all testruns in which idle operation occurs, in order to prevent interference between the engine idle speed controller and the test bed speed controller.

▼M3

4.2.1 Special requirements for dual-fuel engines

Dual-fuel engines shall be operated in dual-fuel mode during all test runs performed in accordance with point 4.3. If a switch to service mode occurs during a test run, all recorded data during the respective test run shall be void.

▼B

4.3 Testruns

4.3.1 Engine full load curve

The engine full load curve shall be recorded in accordance with paragraphs 7.4.1. to 7.4.5. of Annex 4 to ►M3 UN Regulation No. 49 ◄.

4.3.2 Engine motoring curve

The recording of the engine motoring curve in accordance with this paragraph shall be omitted for all other engines except the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3. In accordance with paragraph 6.1.3 the engine motoring curve recorded for the CO_2-parent engine of the engine CO_2-family shall also be applicable to all engines within the same engine CO_2-family.

In the case that upon request of the manufacturer the provisions defined in Article 15(5) of this Regulation are applied, the recording of the engine motoring curve shall be performed additionally for that specific engine.

The engine motoring curve shall be recorded in accordance with option (b) in paragraph 7.4.7. of Annex 4 to ►M3 UN Regulation No. 49 ◄. This test shall determine the negative torque required to motor the engine between maximum and minimum mapping speed with minimum operator demand.

The test shall be continued directly after the full load curve mapping according to paragraph 4.3.1. At the request of the manufacturer, the motoring curve may be recorded separately. In this case the engine oil temperature at the end of the full load curve testrun performed in accordance with paragraph 4.3.1 shall be recorded and the manufacturer shall prove to the satisfaction of the an approval authority, that the engine oil temperature at the starting point of the motoring curve meets the aforementioned temperature within ± 2 K.

At the start of the testrun for the engine motoring curve the engine shall be operated with minimum operator demand at maximum mapping speed defined in paragraph 7.4.3. of Annex 4 to ►M3 UN Regulation No. 49 ◄. As soon as the motoring torque value has stabilized within ± 5 % of its mean value for at least 10 seconds, the data recording shall start and the engine speed shall be decreased at an average rate of 8 ± 1 min^{-1}/s from maximum to minimum mapping speed, which are defined in paragraph 7.4.3. of Annex 4 to ►M3 UN Regulation No. 49 ◄.

▼M3

4.3.2.1 Special requirements for WHR systems

For WHR_mech and WHR_elec systems the data recording for the engine motoring curve shall not start before the reading of the value of mechanical or electrical power generated by the WHR system has stabilised within ± 10 % of its mean value for at least 10 seconds.

4.3.3 WHTC test

The WHTC test shall be performed in accordance with Annex 4 to UN Regulation No. 49. The weighted emission test results shall meet the applicable limits defined in Regulation (EC) No 595/2009.

Dual-fuel engines shall meet the applicable limits in accordance with Annex XVIII, point 5, to Regulation (EU) No 582/2011.

The engine full load curve recorded in accordance with paragraph 4.3.1 shall be used for the denormalisation of the reference cycle and all calculations of reference values performed in accordance with paragraphs 7.4.6, 7.4.7 and 7.4.8 of Annex 4 to UN Regulation No. 49.

▼B

4.3.3.1 Measurement signals and data recording

In addition to the provisions defined in Annex 4 to ►M3 UN Regulation No. 49 ◄ the actual fuel mass flow consumed by the engine in accordance with paragraph 3.4 shall be recorded.

▼M3

4.3.3.2 Special requirements for WHR systems

For WHR_mech systems the mechanical P_WHR_net and for WHR_elec systems the electrical P_WHR_net in accordance with point 3.1.6 shall be recorded.

4.3.4 WHSC test

The WHSC test shall be performed in accordance with Annex 4 to UN Regulation No. 49. The emission test results shall meet the applicable limits defined in Regulation (EC) No 595/2009.

Dual-fuel engines shall meet the applicable limits in accordance with Annex XVIII, point 5, to Regulation (EU) No 582/2011.

The engine full load curve recorded in accordance with point 4.3.1 shall be used for the denormalisation of the reference cycle and all calculations of reference values performed in accordance with paragraphs 7.4.6, 7.4.7 and 7.4.8 of Annex 4 to UN Regulation No. 49.

▼B

4.3.4.1 Measurement signals and data recording

In addition to the provisions defined in Annex 4 to ►M3 UN Regulation No. 49 ◄ the actual fuel mass flow consumed by the engine in accordance with paragraph 3.4 shall be recorded.

▼M3

4.3.4.2 Special requirements for WHR systems

For WHR_mech systems the mechanical P_WHR_net and for WHR_elec systems the electrical P_WHR_net in accordance with point 3.1.6 shall be recorded.

▼B

4.3.5 Fuel consumption mapping cycle (FCMC)

The fuel consumption mapping cycle (FCMC) in accordance with this paragraph shall be omitted for all other engines except the CO_2-parent engine of the engine CO_2-family. The fuel map data recorded for the CO_2-parent engine of the engine CO_2-family shall also be applicable to all engines within the same engine CO_2-family.

In the case that upon request of the manufacturer the provisions defined in Article 15(5) of this Regulation are applied, the fuel consumption mapping cycle shall be performed additionally for that specific engine.

The engine fuel map shall be measured in a series of steady state engine operation points, as defined according to paragraph 4.3.5.2. The metrics of this map are the fuel consumption in g/h depending on engine speed in min^{-1} and engine torque in Nm.

4.3.5.1 Handling of interruptions during the FCMC

If an after-treatment regeneration event occurs during the FCMC for engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis defined in accordance with paragraph 6.6 of Annex 4 to ►M3 UN Regulation No. 49 ◄, all measurements at that engine speed mode shall be void. The regeneration event shall be completed and afterwards the procedure shall be continued as described in paragraph 4.3.5.1.1.

If an unexpected interruption, malfunction or error occurs during the FCMC, all measurements at that engine speed mode shall be void and one of the following options how to continue shall be chosen by the manufacturer:

(1) the procedure shall be continued as described in paragraph 4.3.5.1.1

(2) the whole FCMC shall be repeated in accordance with paragraphs 4.3.5.4 and 4.3.5.5

4.3.5.1.1 Provisions for continuing the FCMC

The engine shall be started and warmed up in accordance with paragraph 7.4.1. of Annex 4 to ►M3 UN Regulation No. 49 ◄. After warm-up, the engine shall be preconditioned by operating the engine for 20 minutes at mode 9, as defined in Table 1 of paragraph 7.2.2. of Annex 4 to ►M3 UN Regulation No. 49 ◄.

The engine full load curve recorded in accordance with paragraph 4.3.1 shall be used for the denormalization of the reference values of mode 9 performed in accordance with paragraphs 7.4.6, 7.4.7 and 7.4.8 of Annex 4 to ►M3 UN Regulation No. 49 ◄.

Directly after completion of preconditioning, the target values for engine speed and torque shall be changed linearly within 20 to 46 seconds to the highest target torque setpoint at the next higher target engine speed setpoint than the particular target engine speed setpoint where the interruption of the FCMC occurred. If the target setpoint is reached within less than 46 seconds, the remaining time up to 46 seconds shall be used for stabilization.

For stabilization the engine operation shall continue from that point in accordance with the test sequence specified in paragraph 4.3.5.5 without recording of measurement values.

▼B

When the highest target torque setpoint at the particular target engine speed setpoint where the interruption occurred is reached, the recording of measurement values shall be continued from that point on in accordance with the test sequence specified in paragraph 4.3.5.5.

4.3.5.2 Grid of target setpoints

The grid of target setpoints is fixed in a normalized way and consists of 10 target engine speed setpoints and 11 target torque setpoints. Conversion of the normalized setpoint definition to the actual target values of engine speed and torque setpoints for the individual engine under test shall be based on the engine full load curve of the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 to this Annex and recorded in accordance with paragraph 4.3.1.

4.3.5.2.1 Definition of target engine speed setpoints

The 10 target engine speed setpoints are defined by 4 base target engine speed setpoints and 6 additional target engine speed setpoints.

The engine speeds n_{idle}, n_{lo}, n_{pref}, n_{95h} and n_{hi} shall be determined from the engine full load curve of the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 to this Annex and recorded in accordance with paragraph 4.3.1 by applying the definitions of characteristic engine speeds in accordance with paragraph 7.4.6. of Annex 4 to ►M3 UN Regulation No. 49 ◄.

The engine speed n_{57} shall be determined by the following equation:

$$n_{57} = 0{,}565 \times (0{,}45 \times n_{lo} + 0{,}45 \times n_{pref} + 0{,}1 \times n_{hi} - n_{idle}) \times 2{,}0327 + n_{idle}$$

The 4 base target engine speed setpoints are defined as follows:

(1) Base engine speed 1: n_{idle}

(2) Base engine speed 2: $n_A = n_{57} - 0{,}05 \times (n_{95h} - n_{idle})$

(3) Base engine speed 3: $n_B = n_{57} + 0{,}08 \times (n_{95h} - n_{idle})$

(4) Base engine speed 4: n_{95h}

The potential distances between the speed setpoints shall be determined by the following equations:

(1) $dn_{idleA\_44} = (n_A - n_{idle}) / 4$

(2) $dn_{B95h\_44} = (n_{95h} - n_B) / 4$

(3) $dn_{idleA\_35} = (n_A - n_{idle}) / 3$

(4) $dn_{B95h\_35} = (n_{95h} - n_B) / 5$

(5) $dn_{idleA\_53} = (n_A - n_{idle}) / 5$

(6) $dn_{B95h\_53} = (n_{95h} - n_B) / 3$

The absolute values of potential deviations between the two sections shall be determined by the following equations:

(1) $dn_{44} = ABS(dn_{idleA\_44} - dn_{B95h\_44})$

(2) $dn_{35} = ABS(dn_{idleA\_35} - dn_{B95h\_35})$

(3) $dn_{53} = ABS(dn_{idleA\_53} - dn_{B95h\_53})$

▼M1

The 6 additional target engine speed setpoints shall be determined in accordance with the following provisions:

(1) If dn_{44} is smaller than or equal to $(dn_{35} + 5)$ and also smaller than or equal to $(dn_{53} + 5)$, the 6 additional target engine speeds shall be determined by dividing each of the two ranges, one from n_{idle} to n_A and the other from n_B to n_{95h}, into 4 equidistant sections.

▼**M1**

(2) If (dn_{35} + 5) is smaller than dn_{44} and also dn_{35} is smaller than dn_{53}, the 6 additional target engine speeds shall be determined by dividing the range from n_{idle} to n_A into 3 equidistant sections and the range from n_B to n_{95h}, into 5 equidistant sections.

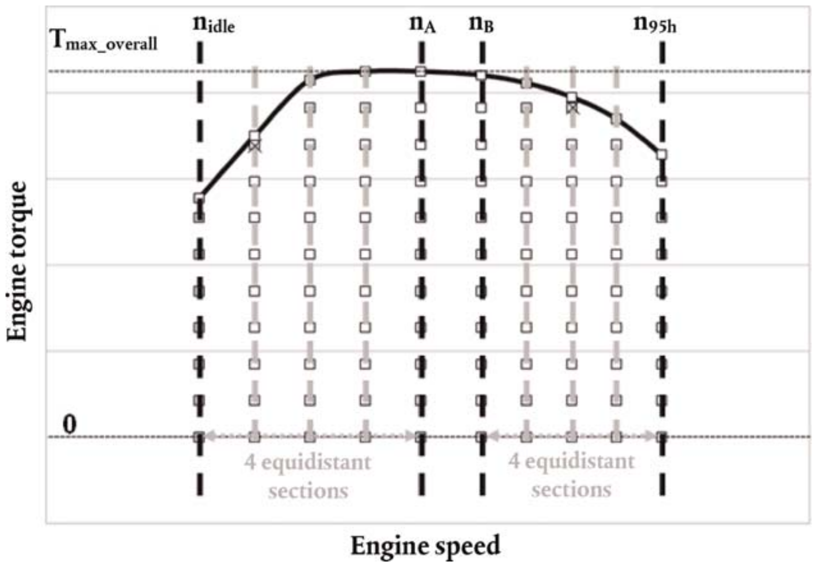
(3) If (dn_{53} + 5) is smaller than dn_{44} and also dn_{53} is smaller than dn_{35}, the 6 additional target engine speeds shall be determined by dividing the range from n_{idle} to n_A into 5 equidistant sections and the range from n_B to n_{95h}, into 3 equidistant sections.

▼**B**

Figure 1 exemplarily illustrates the definition of the target engine speed setpoints according to subpoint (1) above.

Figure 1

Definition of speed setpoints



4.3.5.2.2 Definition of target torque setpoints

The 11 target torque setpoints are defined by 2 base target torque setpoints and 9 additional target torque setpoints. The 2 base target torque setpoints are defined by zero engine torque and the maximum engine full load of the CO_2-parent engine determined in accordance with paragraph 4.3.1. (overall maximum torque $T_{max\_overall}$). The 9 additional target torque setpoints are determined by dividing the range from zero torque to overall maximum torque, $T_{max\_overall}$, into 10 equidistant sections.

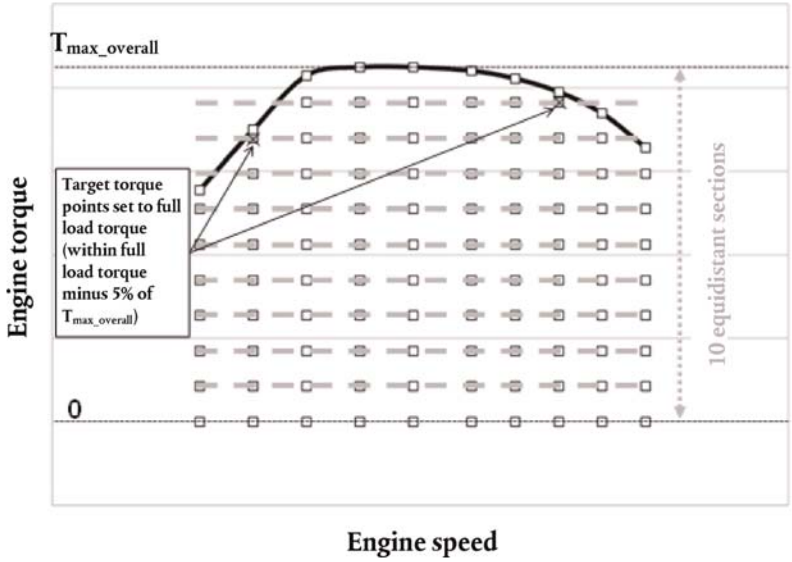
▼**M1**

►**M3** All target torque setpoints at a particular target engine speed setpoint that exceed the limit value defined by the full load torque value (determined from the engine full load curve recorded in accordance with point 4.3.1) at this particular target engine speed setpoint minus 5 % of $T_{max\_overall}$, shall be replaced by one single target torque setpoint at full load torque at this particular target engine speed setpoint. ◄ Each of these replacement setpoints shall be measured only once during the FCMC test sequence defined in accordance with paragraph 4.3.5.5. Figure 2 exemplarily illustrates the definition of the target torque setpoints.

▼B

Figure 2

Definition of torque setpoints



4.3.5.3 Measurement signals and data recording

The following measurement data shall be recorded:

(1) engine speed

(2) engine torque corrected in accordance with paragraph 3.1.2

(3) fuel mass flow consumed by the whole engine system in accordance with paragraph 3.4

(4) Gaseous pollutants according to the definitions in ►M3 UN Regulation No. 49 ◄. ►M3 Particulate pollutants, methane and ammonia emissions are not required to be monitored during the FCMC test run. ◄

The measurement of gaseous pollutants shall be carried out in accordance with paragraphs 7.5.1, 7.5.2, 7.5.3, 7.5.5, 7.7.4, 7.8.1, 7.8.2, 7.8.4 and 7.8.5 of Annex 4 to ►M3 UN Regulation No. 49 ◄.

For the purpose of paragraph 7.8.4 of Annex 4 to ►M3 UN Regulation No. 49 ◄, the term 'test cycle' in the paragraph referred to shall be the complete sequence from preconditioning in accordance with paragraph 4.3.5.4 to ending of the test sequence in accordance with paragraph 4.3.5.5.

▼M3

4.3.5.3.1 Special requirements for WHR systems

For WHR_mech systems the mechanical P_WHR_net and for WHR_elec systems the electrical P_WHR_net in accordance with point 3.1.6 shall be recorded.

▼B

4.3.5.4 Preconditioning of the engine system

The dilution system, if applicable, and the engine shall be started and warmed up in accordance with paragraph 7.4.1. of Annex 4 to ►M3 UN Regulation No. 49 ◄.

After warm-up is completed, the engine and sampling system shall be preconditioned by operating the engine for 20 minutes at mode 9, as defined in Table 1 of paragraph 7.2.2. of Annex 4 to ►M3 UN Regulation No. 49 ◄, while simultaneously operating the dilution system.

▼**M3**

The engine full load curve of the CO_2-parent engine of the engine CO_2-family recorded in accordance with point 4.3.1 shall be used for the denormalisation of the reference values of mode 9 performed in accordance with paragraphs 7.4.6, 7.4.7 and 7.4.8 of Annex 4 to UN Regulation No. 49.

▼**B**

Directly after completion of preconditioning, the target values for engine speed and torque shall be changed linearly within 20 to 46 seconds to match the first target setpoint of the test sequence according to paragraph 4.3.5.5. If the first target setpoint is reached within less than 46 seconds, the remaining time up to 46 seconds shall be used for stabilization.

4.3.5.5 Test sequence

The test sequence consists of steady state target setpoints with defined engine speed and torque at each target setpoint in accordance with paragraph 4.3.5.2 and defined ramps to move from one target setpoint to the next.

The highest target torque setpoint at each target engine speed shall be operated with maximum operator demand.

The first target setpoint is defined at the highest target engine speed setpoint and highest target torque setpoint.

The following steps shall be performed to cover all target setpoints:

(1) The engine shall be operated for 95 ± 3 seconds at each target setpoint. The first 55 ± 1 seconds at each target setpoint are considered as a stabilization period,. ►**M3** During the following period of 30±1 seconds the engine shall be controlled as follows: ◄

(a) The engine speed mean value shall be held at the target engine speed setpoint within ± 1 percent of the highest target engine speed.

(b) Except for the points at full load, the engine torque mean value shall be held at the target torque setpoint within a tolerance of ± 20 Nm or ± 2 percent of the overall maximum torque, $T_{max\_overall}$, whichever is greater.

The recorded values in accordance with paragraph 4.3.5.3 shall be stored as averaged value over the period of 30 ± 1 seconds. The remaining period of 10 ± 1 seconds may be used for data post-processing and storage if necessary. During this period the engine target setpoint shall be kept.

▼B

(2) After the measurement at one target setpoint is completed, the target value for engine speed shall be kept constant within ± 20 min^{-1} of the target engine speed setpoint and the target value for torque shall be decreased linearly within 20±1 seconds to match the next lower target torque setpoint. Then the measurement shall be performed according to subpoint (1).

▼M3

(3) After the zero torque setpoint has been measured in subpoint (1), the target engine speed shall be decreased linearly to the next lower target engine speed setpoint while at the same time the operator demand shall be increased linearly to the maximum value within 20 to 46 seconds. If the next target setpoint is reached within less than 46 seconds, the remaining time up to 46 seconds shall be used for stabilisation. Then the measurement shall be performed by starting the stabilisation procedure in accordance with subpoint (1) and afterwards the target torque setpoints at constant target engine speed shall be adjusted in accordance with subpoint (2).

▼B

Figure 3 illustrates the three different steps to be performed at each measurement setpoint for the test according to subpoint (1) above.

Figure 3

Steps to be performed at each measurement setpoint

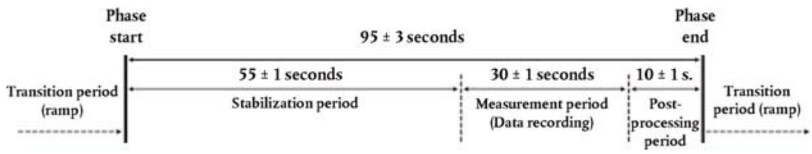
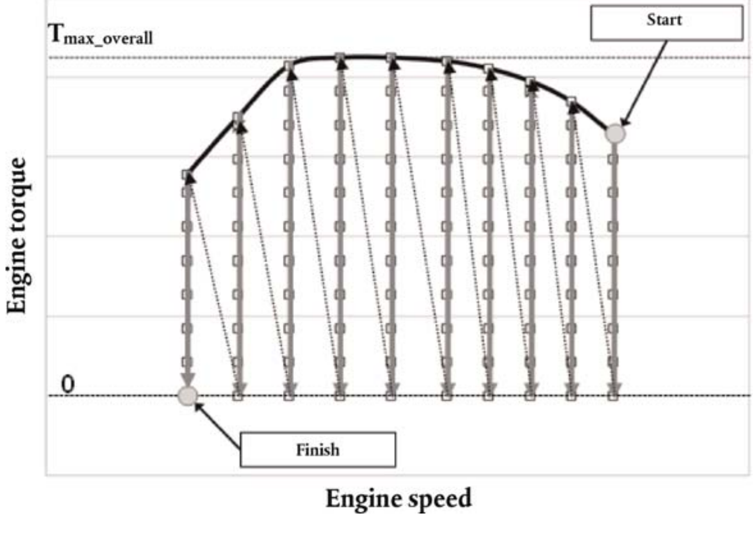


Figure 4 exemplarily illustrates the sequence of steady state measurement setpoints to be followed for the test.

Figure 4

Sequence of steady state measurement setpoints



▼B

4.3.5.6 Data evaluation for emission monitoring

Gaseous pollutants in accordance with paragraph 4.3.5.3 shall be monitored during the FCMC. The definitions of characteristic engine speeds in accordance with paragraph 7.4.6. of Annex 4 to ►M3 UN Regulation No. 49 ◄ shall apply.

4.3.5.6.1 Definition of control area

The control area for emission monitoring during the FCMC shall be determined in accordance with paragraphs 4.3.5.6.1.1 and 4.3.5.6.1.2.

4.3.5.6.1.1 Engine speed range for the control area

(1) The engine speed range for the control area shall be defined based on the engine full load curve of the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 to this Annex and recorded in accordance with paragraph 4.3.1.

(2) The control area shall include all engine speeds greater than or equal to the 30th percentile cumulative speed distribution, determined from all engine speeds including idle speed sorted in ascending order, over the hotstart WHTC test cycle performed in accordance with paragraph 4.3.3 (n_{30}) for the engine full load curve referred to the subpoint (1).

(3) The control area shall include all engine speeds lower than or equal to n_{hi} determined from the engine full load curve referred to in the subpoint (1)

4.3.5.6.1.2 Engine torque and power range for the control area

(1) The lower boundary of the engine torque range for the control area shall be defined based on the engine full load curve of the engine with the lowest rating of all engines within the engine CO_2-family and recorded in accordance with paragraph 4.3.1.

(2) The control area shall include all engine load points with a torque value greater than or equal to 30 percent of the maximum torque value determined from the engine full load curve referred to in subpoint (1).

(3) Notwithstanding the provisions of subpoint (2), speed and torque points below 30 percent of the maximum power value, determined from the engine full load curve referred to in subpoint (1), shall be excluded from the control area.

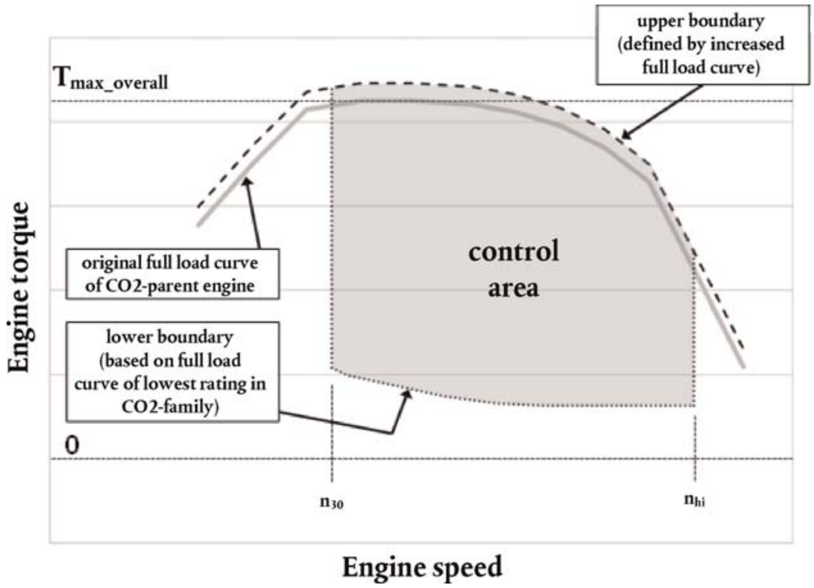
(4) Notwithstanding the provisions of subpoints (2) and (3), the upper boundary of the control area shall be based on the engine full load curve of the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 to this Annex and recorded in accordance with paragraph 4.3.1. The torque value for each engine speed determined from the engine full load curve of the CO_2-parent engine shall be increased by 5 percent of the overall maximum torque, $T_{max\_overall}$, defined in accordance with paragraph 4.3.5.2.2. The modified increased engine full load curve of the CO_2-parent engine shall be used as upper boundary of the control area.

Figure 5 exemplarily illustrates the definition of the engine speed, torque and power range for the control area.

▼B

Figure 5

Definition of the engine speed, torque and power range for the control area exemplarily



4.3.5.6.2 Definition of the grid cells

The control area defined in accordance with paragraph 4.3.5.6.1 shall be divided into a number of grid cells for emission monitoring during the FCMC.

The grid shall comprise of 9 cells for engines with a rated speed less than 3 000 min^{-1} and 12 cells for engines with a rated speed greater than or equal to 3 000 min^{-1}. The grids shall be defined in accordance with the following provisions:

(1) The outer boundaries of the grids are aligned to the control area defined according to paragraph 4.3.5.6.1.

▼M3

(2) 2 vertical lines spaced at equal distance between engine speeds n_{30} and n_{hi} for 9 cell grids, or 3 vertical lines spaced at equal distance between engine speeds n_{30} and n_{hi} for 12 cell grids.

(3) 2 lines spaced at equal distance of engine torque (i.e. 1/3) at each vertical line within the control area defined in accordance with point 4.3.5.6.1.

▼B

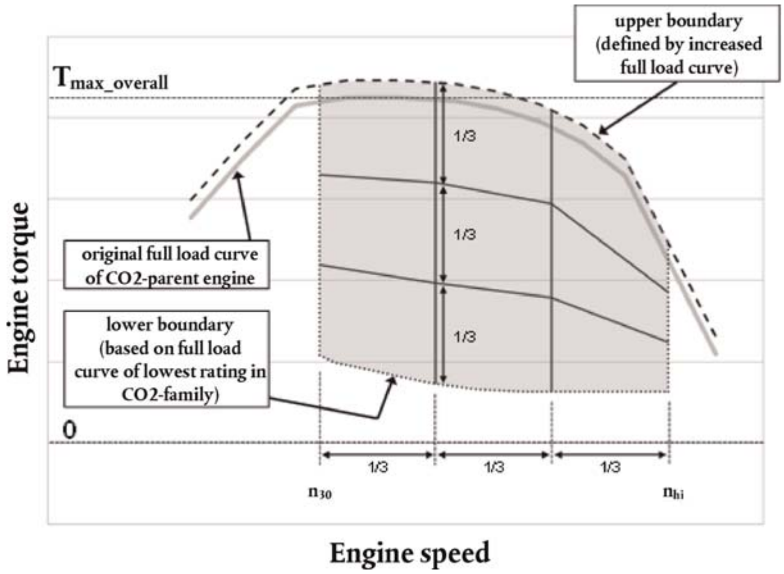
All engine speed values in min^{-1} and all torque values in Newton-meters defining the boundaries of the grid cells shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

Figure 6 exemplarily illustrates the definition of the grid cells for the control area in the case of 9 cell grid.

▼B

Figure 6

Definition of the grid cells for the control area exemplarily for 9 cell grid



4.3.5.6.3 Calculation of specific mass emissions

The specific mass emissions of the gaseous pollutants shall be determined as average value for each grid cell defined in accordance with paragraph 4.3.5.6.2. The average value for each grid cell shall be determined as arithmetical mean value of the specific mass emissions over all engine speed and torque points measured during the FCMC located within the same grid cell.

▼M3

The specific mass emissions of the single engine speed and torque points measured during the FCMC shall be determined as averaged value over the 30±1 seconds measurement period defined in accordance with point 4.3.5.5., subpoint (1)

▼B

If an engine speed and torque point is located directly on a line that separates different grid cells from each other, this engine speed and load point shall be taken into account for the average values of all adjacent grid cells.

The calculation of the total mass emissions of each gaseous pollutant for each engine speed and torque point measured during the FCMC, $m_{FCMC,i}$ in grams, over the 30 ± 1 seconds measurement period in accordance with subpoint (1) of paragraph 4.3.5.5 shall be carried out in accordance with paragraph 8 of Annex 4 to ►M3 UN Regulation No. 49 ◄.

The actual engine work for each engine speed and torque point measured during the FCMC, $W_{FCMC,i}$ in kWh, over the 30 ± 1 seconds measurement period in accordance with subpoint (1) of paragraph 4.3.5.5 shall be determined from the engine speed and torque values recorded in accordance with paragraph 4.3.5.3.

The specific mass emissions of gaseous pollutants $e_{FCMC,i}$ in g/kWh for each engine speed and torque point measured during the FCMC shall be determined by the following equation:

$$e_{FCMC,i} = m_{FCMC,i} / W_{FCMC,i}$$

▼B

4.3.5.7 Validity of data

4.3.5.7.1 Requirements for validation statistics of the FCMC

A linear regression analysis of the actual values of engine speed (n_{act}), engine torque (M_{act}) and engine power (P_{act}) on the respective reference values (n_{ref}, M_{ref}, P_{ref}) shall be performed for the FCMC. The actual values for n_{act}, M_{act} and P_{act} shall be the determined from the values recorded in accordance with paragraph 4.3.5.3.

The ramps to move from one target setpoint to the next shall be excluded from this regression analysis.

To minimize the biasing effect of the time lag between the actual and reference cycle values, the entire engine speed and torque actual signal sequence may be advanced or delayed in time with respect to the reference speed and torque sequence. If the actual signals are shifted, both speed and torque shall be shifted by the same amount in the same direction.

The method of least squares shall be used for the regression analysis in accordance with paragraphs A.3.1 and A.3.2 of Appendix 3 to Annex 4 to ►M3 UN Regulation No. 49 ◄, with the best-fit equation having the form as defined in paragraph 7.8.7 of Annex 4 to ►M3 UN Regulation No. 49 ◄. It is recommended that this analysis be performed at 1 Hz.

For the purposes of this regression analysis only, omissions of points are permitted where noted in Table 4 (Permitted point omissions from regression analysis) of Annex 4 to ►M3 UN Regulation No. 49 ◄ before doing the regression calculation. Additionally, all engine torque and power values at points with maximum operator demand shall be omitted for the purposes of this regression analysis only. However, points omitted for the purposes of regression analysis shall not be omitted for any other calculations in accordance with this Annex. Point omission may be applied to the whole or to any part of the cycle.

For the data to be considered valid, the criteria of Table 3 (Regression line tolerances for the WHSC) of Annex 4 to ►M3 UN Regulation No. 49 ◄ shall be met.

▼M3

4.3.5.7.2 Requirements for emission monitoring

The data obtained from the FCMC tests is valid if the specific mass emissions of the regulated gaseous pollutants determined for each grid cell in accordance with point 4.3.5.6.3 meet the following limits for gaseous pollutants:

(a) Engines other than dual-fuel shall meet the applicable limit values in accordance with paragraph 5.2.2 of Annex 10 to UN Regulation 49.

(b) Dual-fuel engines shall meet the applicable limits defined in Annex XVIII to Regulation (EU) No 582/2011, where reference to a pollutant emission limit defined in Annex I to Regulation (EU) 595/2009 shall be replaced by reference to the limit of the same pollutant in accordance with paragraph 5.2.2 of Annex 10 to UN/ECE Regulation 49.

In the case that the number of engine speed and torque points within the same grid cell is less than 3, this point shall not apply for that specific grid cell.

▼B

5. Post-processing of measurement data

All calculations defined in this paragraph shall be performed specifically for each engine within one engine CO_2-family.

5.1 Calculation of engine work

▼M1

Total engine work over a cycle or a defined period shall be determined from the recorded values of engine power determined in accordance with paragraph 3.1.2 of this Annex and paragraphs 6.3.5 and 7.4.8 of Annex 4 to ►M3 UN Regulation No. 49 ◄.

▼B

The engine work over a complete testcycle or over each WHTC-sub-cycle shall be determined by integrating of recorded values of engine power in accordance with the following formula:

$$W_{act,i} = \left(\frac{1}{2}P_0 + P_1 + P_2 + \ ... + P_{n-2} + P_{n-1} + \frac{1}{2}P_n\right)h$$

where:

$W_{act,\ i}$ = total engine work over the time period from t_0 to t_1

t_0 = time at the start of the time period

t_1 = time at the end of the time period

n = number of recorded values over the time period from t_0 to t_1

$P_{k\ [0\ ...\ n]}$ = recorded engine power values over the time period from t_0 to t_1 in chronological order, where k runs from 0 at t_0 to n at t_1

h = interval width between two adjacent recorded values defined by $h = \frac{t_1 - t_0}{n}$

5.2 Calculation of integrated fuel consumption

Any recorded negative values for the fuel consumption shall be used directly and shall not be set equal to zero for the calculations of the integrated value.

The total fuel mass consumed by the engine over a complete testcycle or over each WHTC-sub-cycle shall be determined by integrating recorded values of fuel massflow in accordance with the following formula:

$$\sum FC_{meas,i} = \left(\frac{1}{2}mf_{fuel,0} + mf_{fuel,1} + mf_{fuel,2} + ... + mf_{fuel,n-2} + mf_{fuel,n-1} + \frac{1}{2}mf_{fuel,n}\right)h$$

where:

$\Sigma\ FC_{meas,\ i}$ = total fuel mass consumed by the engine over the time period from t_0 to t_1

t_0 = time at the start of the time period

t_1 = time at the end of the time period

n = number of recorded values over the time period from t_0 to t_1

$mf_{fuel,k\ [0\ ...\ n]}$ = recorded fuel massflow values over the time period from t_0 to t_1 in chronological order, where k runs from 0 at t_0 to n at t_1

▼B

h = interval width between two adjacent recorded values defined by $h = \frac{t_1 - t_0}{n}$

5.3 Calculation of specific fuel consumption figures

The correction and balancing factors, which have to be provided as input for the simulation tool, are calculated by the engine pre-processing tool based on the measured specific fuel consumption figures of the engine determined in accordance with paragraphs 5.3.1 and 5.3.2.

5.3.1 Specific fuel consumption figures for WHTC correction factor

The specific fuel consumption figures needed for the WHTC correction factor shall be calculated from the actual measured values for the hotstart WHTC recorded in accordance with paragraph 4.3.3 as follows:

$$SFC_{meas,\ Urban} = \Sigma\ FC_{meas,\ WHTC\text{-}Urban} / W_{act,\ WHTC\text{-}Urban}$$

$$SFC_{meas,\ Rural} = \Sigma\ FC_{meas,\ WHTC\text{-}\ Rural} / W_{act,\ WHTC\text{-}\ Rural}$$

$$SFC_{meas,\ MW} = \Sigma\ FC_{meas,\ WHTC\text{-}MW} / W_{act,\ WHTC\text{-}M})$$

where:

$SFC_{meas,\ i}$ = Specific fuel consumption over the WHTC-sub-cycle i [g/kWh]

$\Sigma\ FC_{meas,\ i}$ = Total fuel mass consumed by the engine over the WHTC-sub-cycle i [g] determined in accordance with paragraph 5.2

$W_{act,\ i}$ = Total engine work over the WHTC sub-cycle i [kWh] determined in accordance with paragraph 5.1

The 3 different sub-cycles of the WHTC – urban, rural and motorway – shall be defined as follows:

(1) urban: from cycle start to ≤ 900 seconds from cycle start

(2) rural: from > 900 seconds to ≤ 1 380 seconds from cycle start

(3) motorway (MW): from > 1 380 seconds from cycle start to cycle end

▼M3

5.3.1.1 Special requirements for dual-fuel engines

For dual-fuel engines the specific fuel consumption figures for WHTC correction factor in accordance with point 5.3.1 shall be calculated for each of the two fuels separately.

▼B

5.3.2 Specific fuel consumption figures for cold-hot emission balancing factor

The specific fuel consumption figures needed for the cold-hot emission balancing factor shall be calculated from the actual measured values for both, the hotstart and coldstart WHTC test recorded in accordance with paragraph 4.3.3. The calculations shall be performed for both, the hotstart and coldstart WHTC separately as follows:

$$SFC_{meas,\ hot} = \Sigma\ FC_{meas,\ hot} / W_{act,\ hot}$$

$$SFC_{meas,\ cold} = \Sigma\ FC_{meas,\ cold} / W_{act,\ cold}$$

▼B

where:

$SFC_{meas,\ j}$ = Specific fuel consumption [g/kWh]

$\Sigma\ FC_{meas,\ j}$ = Total fuel consumption over the WHTC [g] determined in accordance with paragraph 5.2 of this Annex

$W_{act,\ j}$ = Total engine work over the WHTC [kWh] determined in accordance with paragraph 5.1 of this Annex

▼M3

5.3.2.1 Special requirements for dual-fuel engines

For dual-fuel engines the specific fuel consumption figures for cold-hot emission balancing factor in accordance with point 5.3.2 shall be calculated for each of the two fuels separately.

5.3.3 Specific fuel consumption figures over WHSC

The specific fuel consumption over the WHSC shall be calculated from the actual measured values for the WHSC recorded in accordance with point 4.3.4 as follows:

$$SFC_{WHSC} = (\Sigma\ FC_{WHSC}) / (W_{WHSC} + \Sigma\ E\_WHR_{WHSC})$$

where:

SFC_{WHSC} = Specific fuel consumption over WHSC [g/kWh]

$\Sigma\ FC_{WHSC}$ = Total fuel consumption over the WHSC [g]

determined in accordance with point 5.2 of this Annex

W_{WHSC} = Total engine work over the WHSC [kWh]

dddetermined in accordance with point 5.1 of this Annex

For engines with more than one WHR system installed E_WHR_{WHSC} shall be calculated for each different WHR system separately. For engines without a WHR system installed E_WHR_{WHSC} shall be set to zero.

E_WHR_{WHSC} = Total integrated E_WHR_net over the WHSC [kWh]

determined in accordance with point 5.3

$\Sigma\ E\_WHR_{WHSC}$ = Sum of individual E_WHR_{WHSC} of all different WHR systems installed [kWh].

▼B

5.3.3.1 Corrected specific fuel consumption figures over WHSC

The calculated specific fuel consumption over the WHSC, SFC_{WHSC}, determined in accordance with paragraph 5.3.3 shall be adjusted to a corrected value, $SFC_{WHSC,corr}$, in order to account for the difference between the NCV of the fuel used during testing and the standard NCV for the respective engine fuel technology in accordance with the following equation:

$$SFC_{WHSC,corr} = SFC_{WHSC} \frac{NCV_{meas}}{NCV_{std}}$$

where:

$SFC_{WHSC,corr}$ = Corrected specific fuel consumption over WHSC [g/kWh]

SFC_{WHSC} = Specific fuel consumption over WHSC [g/kWh]

▼B

NCV_{meas} = NCV of the fuel used during testing determined in accordance with paragraph 3.2 [MJ/kg]

NCV_{std} = Standard NCV in accordance with Table 4 [MJ/kg]

Table 4

Standard net calorific values of fuel types

Fuel type / engine type	Reference fuel type	Standard NCV [MJ/kg]
Diesel / CI	B7	42,7
Ethanol / CI	ED95	25,7
Petrol / PI	E10	41,5
Ethanol / PI	E85	29,1
LPG / PI	LPG Fuel B	46,0
▼M1 ►M3 Natural gas / PI or Natural Gas / CI ◄	G_{25} or G_R	45,1

▼B

5.3.3.2 Special provisions for B7 reference fuel

In the case that reference fuel of the type B7 (Diesel /CI) in accordance with paragraph 3.2 was used during testing, the standardization correction in accordance with paragraph 5.3.3.1 shall not be performed and the corrected value, $SFC_{WHSC,corr}$, shall be set to the uncorrected value SFC_{WHSC}.

▼M3

5.3.3.3 Special requirements for dual-fuel engines

For dual-fuel engines the corrected specific fuel consumption figures over the WHSC in accordance with point 5.3.3.1 shall be calculated for each of the two fuels separately from the respective specific fuel consumption figures over the WHSC determined for each of the two fuels separately in accordance with point 5.3.3.

Point 5.3.3.2 shall apply for Diesel fuel B7.

▼B

5.4 Correction factor for engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis

For engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis defined in accordance with paragraph 6.6.1 of Annex 4 to ►M3 UN Regulation No. 49 ◄, fuel consumption shall be adjusted to account for regeneration events by a correction factor.

This correction factor, CF_{RegPer}, shall be determined in accordance with paragraph 6.6.2 of Annex 4 to ►M3 UN Regulation No. 49 ◄.

For engines equipped with exhaust after-treatment systems with continuous regeneration, defined in accordance with paragraph 6.6 of Annex 4 to ►M3 UN Regulation No. 49 ◄, no correction factor shall be determined and the value of the factor CF_{RegPer} shall be set to 1.

The engine full load curve recorded in accordance with paragraph 4.3.1 shall be used for the denormalization of the WHTC reference cycle and all calculations of reference values performed in accordance with paragraphs 7.4.6, 7.4.7 and 7.4.8 of Annex 4 to ►M3 UN Regulation No. 49 ◄.

▼B

In addition to the provisions defined in Annex 4 to ►M3 UN Regulation No. 49 ◄ the actual fuel mass flow consumed by the engine in accordance with paragraph 3.4 shall be recorded for each WHTC hot start test performed in accordance with paragraph 6.6.2 of Annex 4 to ►M3 UN Regulation No. 49 ◄.

The specific fuel consumption for each WHTC hot start test performed shall be calculated by the following equation:

$$SFC_{meas,\ m} = (\Sigma\ FC_{meas,\ m}) \ /\ (W_{act,\ m})$$

where:

$SFC_{meas,\ m}$ = Specific fuel consumption [g/kWh]

$\Sigma\ FC_{meas,m}$ = Total fuel consumption over the WHTC [g] determined in accordance with paragraph 5.2 of this Annex

$W_{act,\ m}$ = Total engine work over the WHTC [kWh] determined in accordance with paragraph 5.1 of this Annex

m = Index defining each individual WHTC hot start test

The specific fuel consumption values for the individual WHTC tests shall be weighted by the following equation:

$$SFC_w = \frac{n \times SFC_{avg} + n_r \times SFC_{avg,r}}{n + n_r}$$

where:

n = the number of WHTC hot start tests without regeneration

n_r = the number of WHTC hot start tests with regeneration (minimum number is one test)

SFC_{avg} = the average specific fuel consumption from all WHTC hot start tests without regeneration [g/kWh]

$SFC_{avg,r}$ = the average specific fuel consumption from all WHTC hot start tests with regeneration [g/kWh]

The correction factor, CF_{RegPer}, shall be calculated by the following equation:

$$CF_{RegPer} = \frac{SFC_w}{SFC_{avg}}$$

▼M3

5.4.1 Special requirements for dual-fuel engines

For dual-fuel engines the correction factor for engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis in accordance with point 5.4 shall be calculated for each of the two fuels separately.

5.5 Special provisions for WHR systems

The values in subpoints 5.5.1, 5.5.2 and 5.5.3 shall only be calculated where a WHR_mech or WHR_elec system is present in the test setup. The respective values shall be calculated for mechanical and electrical net power separately.

▼M3

5.5.1 Calculation of integrated E_WHR_net

This paragraph shall only apply to engines with WHR systems.

Any recorded negative values for the mechanical or electrical P_WHR_net shall be used directly and shall not be set equal to zero for the calculations of the integrated value.

The total integrated E_WHR_net over a complete testcycle or over each WHTC-sub-cycle shall be determined by integrating recorded values of mechanical or electrical P_WHR_net in accordance with the following formula:

$$E_W HR_{meas,i} = \left(\frac{1}{2} P_W HR_{meas,0} + P_W HR_{meas,1} + P_W HR_{meas,2} + \ldots + P_W HR_{meas,n-2} + P_W HR_{meas,n-1} + \frac{1}{2} P_W HR_{meas,n}\right) h$$

where:

$E\_WHR_{meas,\ i}$	= total integrated E_WHR_net over the time period from t_0 to t_1
t_0	= time at the start of the time period
t_1	= time at the end of the time period
n	= number of recorded values over the time period from t_0 to t_1
$P\_WHR_{meas,k\ [0\ \ldots\ n]}$	= recorded mechanical or electrical P_WHR_net value at the moment $t_0 + k \times h$, over the time period from t_0 to t_1 in chronological order, where k runs from 0 at t_0 to n at t_1
$h = \frac{t_1 - t_0}{n}$ h	= interval width between two adjacent recorded values

5.5.2 Calculation of specific E_WHR_net figures

The correction and balancing factors, which have to be provided as input for the simulation tool, are calculated by the engine pre-processing tool based on the measured specific E_WHR_net figures determined in accordance with points 5.5.2.1 and 5.5.2.2.

5.5.2.1 Specific E_WHR_net figures for WHTC correction factor

The specific E_WHR_net figures needed for the WHTC correction factor shall be calculated from the actual measured values for the hotstart WHTC recorded in accordance with point 4.3.3 as follows:

$$S\_E\_WHR_{meas,\ Urban} = E\_WHR_{meas,\ WHTC\text{-}Urban} / W_{act,\ WHTC\text{-}Urban}$$

$$S\_E\_WHR_{meas,\ Rural} = E\_WHR_{meas,\ WHTC\text{-}\ Rural} / W_{act,\ WHTC\text{-}\ Rural}$$

$$S\_E\_WHR_{meas,\ MW} = E\_WHR_{meas,\ WHTC\text{-}MW} / W_{act,\ WHTC\text{-}MW}$$

where:

$S\_E\_WHR_{meas,\ i}$	= Specific E_WHR_net over the WHTC-sub-cycle i [kJ/kWh]
$E\_WHR_{meas,\ i}$	= Total integrated E_WHR_net over the WHTC-sub-cycle i [kJ] determined in accordance with point 5.5.1

▼M3

$W_{act, i}$ = Total engine work over the WHTC sub-cycle i [kWh]

determined in accordance with point 5.1

The 3 different sub-cycles of the WHTC (urban, rural and motorway) as defined in point 5.3.1.

5.5.2.2 Specific E_WHR_net figures for cold-hot emission balancing factor

The specific E_WHR_net figures needed for the cold-hot emission balancing factor shall be calculated from the actual measured values for both the hotstart and coldstart WHTC test recorded in accordance with point 4.3.3. The calculations shall be performed for both the hotstart and coldstart WHTC separately as follows:

$$S\_E\_WHR_{meas,\ hot} = E\_WHR_{meas,\ hot} / W_{act,\ hot}$$

$$S\_E\_WHR_{meas,\ cold} = E\_WHR_{meas,\ cold} / W_{act,\ cold}$$

where:

$S\_E\_WHR_{meas,\ j}$ = Specific E_WHR_net over the WHTC [kJ/kWh]

$E\_WHR_{meas,\ j}$ = Total integrated E_WHR_net over the WHTC [kJ]

determined in accordance with point 5.5.1

$W_{act,\ j}$ = Total engine work over the WHTC [kWh]

determined in accordance with point 5.1

5.5.3 WHR correction factor for engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis

This correction factor shall be set to 1.;

▼B

6. Application of engine pre-processing tool

The engine pre-processing tool shall be executed for each engine within one engine CO_2-family using the input defined in paragraph 6.1.

The output data of the engine pre-processing tool shall be the final result of the engine test procedure and shall be documented.

6.1 Input data for the engine pre-processing tool

The following input data shall be generated by the test procedures specified in this Annex and shall be the input to the engine pre-processing tool.

6.1.1 Full load curve of the CO_2-parent engine

The input data shall be the engine full load curve of the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 to this Annex and recorded in accordance with paragraph 4.3.1.

In the case that upon request of the manufacturer the provisions defined in Article 15(5) of this Regulation are applied, the engine full load curve of that specific engine recorded in accordance with paragraph 4.3.1 shall be used as input data.

▼B

The input data shall be provided in the file format of ‘comma separated values’ with the separator character being the Unicode Character ‘COMMA’ (U+002C) (‘,’). The first line of the file shall be used as a header and not contain any recorded data. The recorded data shall start from the second line of the file.

The first column of the file shall be the engine speed in min^{-1} rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06. The second column shall be the torque in Nm rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

6.1.2 Full load curve

The input data shall be the engine full load curve of the engine recorded in accordance with paragraph 4.3.1.

The input data shall be provided in the file format of ‘comma separated values’ with the separator character being the Unicode Character ‘COMMA’ (U+002C) (‘,’). The first line of the file shall be used as a header and not contain any recorded data. The recorded data shall start from the second line of the file.

The first column of the file shall be the engine speed in min^{-1} rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06. The second column shall be the torque in Nm rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

6.1.3 Motoring curve of the CO_2-parent engine

The input data shall be the engine motoring curve of the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 to this Annex and recorded in accordance with paragraph 4.3.2.

In the case that upon request of the manufacturer the provisions defined in Article 15(5) of this Regulation are applied, the engine motoring curve of that specific engine recorded in accordance with paragraph 4.3.2 shall be used as input data.

The input data shall be provided in the file format of ‘comma separated values’ with the separator character being the Unicode Character ‘COMMA’ (U+002C) (‘,’). The first line of the file shall be used as a header and not contain any recorded data. The recorded data shall start from the second line of the file.

The first column of the file shall be the engine speed in min^{-1} rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06. The second column shall be the torque in Nm rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

▼M3

6.1.4 Fuel consumption map of the CO_2-parent engine

The input data shall be the values determined for the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 of this Annex and recorded in accordance with point 4.3.5.

In the case that upon request of the manufacturer the provisions defined in Article 15(5) of this Regulation are applied, the values determined for that specific engine recorded in accordance with point 4.3.5 shall be used as input data.

The input data shall only consist of the average measurement values over the 30±1 seconds measurement period determined in accordance with subpoint (1) of point 4.3.5.5.

▼M3

The input data shall be provided in the file format of "comma separated values" with the separator character being the Unicode Character 'COMMA' (U+002C) (','). The first line of the file shall be used as a heading and not contain any recorded data. The recorded data shall start from the second line of the file.

The heading of each column in the first line of the file defines the expected content of the respective column.

The column for engine speed shall have the string 'engine speed' as heading in the first line of the file. The data values shall start from the second line of the file in min^{-1} rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

The column for torque shall have the string 'torque' as heading in the first line of the file. The data values shall start from the second line of the file in Nm rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

The column for fuel massflow shall have the string 'massflow fuel 1' as heading in the first line of the file. The data values shall start from the second line of the file in g/h rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

6.1.4.1 Special requirements for dual-fuel engines

The column for fuel massflow of the second fuel measured shall have the string 'massflow fuel 2' as heading in the first line of the file. The data values shall start from the second line of the file in g/h rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

6.1.4.2 Special requirements for engines equipped with a WHR system

Where the WHR system is of the type 'WHR_mech' or 'WHR_elec', the input data shall be extended with the values for the mechanical P_WHR_net for WHR_mech systems or with the values for the electrical P_WHR_net for WHR_elec systems recorded in accordance with point 4.3.5.3.1.

The column for the mechanical P_WHR_net shall have the string 'WHR mechanical power' and the column for the electrical P_WHR_net shall have the string "WHR electrical power" as heading in the first line of the file. The data values shall start from the second line of the file in W rounded to the nearest whole number in accordance with ASTM E 29-06.

▼B

6.1.5 Specific fuel consumption figures for WHTC correction factor

The input data shall be the three values for specific fuel consumption over the different sub-cycles of the WHTC – urban, rural and motorway – in g/kWh determined in accordance with paragraph 5.3.1.

The values shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

▼M3

6.1.5.1 Special requirements for dual-fuel engines

The three values determined in accordance with point 6.1.5 corresponding to the respective fuel type used as input for the column 'massflow fuel 1' in accordance with point 6.1.4 shall be the input data under the tab 'Fuel 1' in the GUI.

▼M3

The three values determined in accordance with point 6.1.5 corresponding to the respective fuel type used as input for the column 'massflow fuel 2' in accordance with point 6.1.4.1 shall be the input data under the tab 'Fuel 2' in the GUI.

▼B

6.1.6 Specific fuel consumption figures for cold-hot emission balancing factor

The input data shall be the two values for specific fuel consumption over the hotstart and coldstart WHTC in g/kWh determined in accordance with paragraph 5.3.2.

The values shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

▼M3

6.1.6.1 Special requirements for dual-fuel engines

The values determined in accordance with point 6.1.6 corresponding to the respective fuel type used as input for the column 'massflow fuel 1' in accordance with point 6.1.4 shall be the input data under the tab 'Fuel 1' in the GUI.

The values determined in accordance with point 6.1.6 corresponding to the respective fuel type used as input for the column 'massflow fuel 2' in accordance with point 6.1.4.1 shall be the input data under the tab 'Fuel 2' in the GUI.

▼B

6.1.7 Correction factor for engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis

The input data shall be the correction factor CF_{RegPer} determined in accordance with paragraph 5.4.

For engines equipped with exhaust after-treatment systems with continuous regeneration, defined in accordance with paragraph 6.6.1 of Annex 4 to UN/ECERegulation 49 Rev.06, this factor shall be set to 1 in accordance with paragraph5.4.

The value shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

▼M3

6.1.7.1 Special requirements for dual-fuel engines

The values determined in accordance with point 6.1.7 corresponding to the respective fuel type used as input for the column 'massflow fuel 1' in accordance with point 6.1.4 shall be the input data under the tab 'Fuel 1' in the GUI.

The values determined in accordance with point 6.1.7 corresponding to the respective fuel type used as input for the column 'massflow fuel 2' in accordance with point 6.1.4.1 shall be the input data under the tab 'Fuel 2' in the GUI.

▼B

6.1.8 NCV of test fuel

The input data shall be the NCV of the test fuel in MJ/kg determined in accordance with paragraph 3.2.

▼M1

The value shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06.

▼M3

6.1.8.1 Special requirements for dual-fuel engines

The value determined in accordance with point 6.1.8 corresponding to the respective fuel type used as input for the column 'massflow fuel 1' in accordance with point 6.1.4 shall be the input data under the tab 'Fuel 1' in the GUI.

▼M3

The value determined in accordance with point 6.1.8 corresponding to the respective fuel type used as input for the column 'massflow fuel 2' in accordance with point 6.1.4.1 shall be the input data under the tab 'Fuel 2' in the GUI.

▼B

6.1.9 Type of test fuel

The input data shall be the type of the test fuel selected in accordance with paragraph 3.2.

▼M3

6.1.9.1 Special requirements for dual-fuel engines

The type of the test fuel corresponding to the respective fuel type used as input for the column 'massflow fuel 1' in accordance with point 6.1.4 shall be the input data under the tab 'Fuel 1' in the GUI.

The type of the test fuel corresponding to the respective fuel type used as input for the column 'massflow fuel 2' in accordance with point 6.1.4.1 shall be the input data under the tab 'Fuel 2' in the GUI.

▼B

6.1.10 Engine idle speed of the CO_2-parent engine

The input data shall be the engine idle speed, n_{idle}, in min^{-1} of the CO_2-parent engine of the engine CO_2-family defined in accordance with Appendix 3 to this Annex as declared by the manufacturer in the application for certification in the information document drawn up in accordance with the model set out in Appendix 2.

In the case that upon request of the manufacturer the provisions defined in Article 15(5) of this Regulation are applied, the engine idle speed of that specific engine shall be used as input data.

The value shall be rounded to the nearest whole number in accordance with ASTM E 29-06.

6.1.11 Engine idle speed

The input data shall be the engine idle speed, n_{idle}, in min^{-1} of the engine as declared by the manufacturer in the application for certification in the information document drawn up in accordance with the model set out in Appendix 2 to this Annex.

The value shall be rounded to the nearest whole number in accordance with ASTM E 29-06.

6.1.12 Engine displacement

The input data shall be the displacement in ccm of the engine as declared by the manufacturer at the application for certification in the information document drawn up in accordance with the model set out in Appendix 2 to this Annex.

The value shall be rounded to the nearest whole number in accordance with ASTM E 29-06.

6.1.13 Engine rated speed

The input data shall be the rated speed in min^{-1} of the engine as declared by the manufacturer at the application for certification in point 3.2.1.8. of the information document in accordance with Appendix 2 to this Annex.

The value shall be rounded to the nearest whole number in accordance with ASTM E 29-06.

▼B

6.1.14 Engine rated power

The input data shall be the rated power in kW of the engine as declared by the manufacturer at the application for certification in point 3.2.1.8. of the information document in accordance with Appendix 2 to this Annex.

The value shall be rounded to the nearest whole number in accordance with ASTM E 29-06.

6.1.15 Manufacturer

The input data shall be the name of the engine manufacturer as a sequence of characters in ISO8859-1 encoding.

6.1.16 Model

The input data shall be the name of the engine model as a sequence of characters in ISO8859-1 encoding.

▼M3

6.1.17 Certification Number

The input data shall be the certification number of the engine as a sequence of characters in ISO8859-1 encoding.

6.1.18 Dual-fuel

In the case of a dual-fuel engine, the checkbox 'Dual-fuel' in the GUI shall be set to active.

6.1.19 WHR_no_ext

In the case of an engine with a WHR_no_ext system, the checkbox 'MechanicalOutputICE' in the GUI shall be set to active.

6.1.20 WHR_mech

In the case of an engine with a WHR_mech system, the checkbox 'MechanicalOutputDrivetrain' in the GUI shall be set to active.

6.1.21 WHR_elec

In the case of an engine with a WHR_elec system, the checkbox 'ElectricalOutput' in the GUI shall be set to active.

6.1.22 Specific E_WHR_net figures for WHTC correction factor for WHR_mech systems

In the case of an engine with a WHR_mech system, the input data shall be the three values for specific E_WHR_net over the different sub-cycles of the WHTC – urban, rural and motorway – in kJ/kWh determined in accordance with point 5.5.2.1.

The values shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06 and shall be the input under the respective fields in the tab 'WHR Mechanical' in the GUI.

6.1.23 Specific E_WHR_net figures for cold-hot emission balancing factor for WHR_mech systems

In the case of an engine with a WHR_mech system, the input data shall be the two values for specific E_WHR_net over the hotstart and coldstart WHTC in kJ/kWh determined in accordance with point 5.5.2.2.

The values shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06 and shall be the input under the respective fields in the tab 'WHR Mechanical' in the GUI.

6.1.24 Specific E_WHR_net figures for WHTC correction factor for WHR_elec systems

In the case of an engine with a WHR_ elec system, the input data shall be the three values for specific E_WHR_net over the different sub-cycles of the WHTC – urban, rural and motorway – in kJ/kWh determined in accordance with point 5.5.2.1.

▼M3

The values shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06 and shall be the input under the respective fields in the tab 'WHR Electrical' in the GUI.

6.1.25 Specific E_WHR_net figures for cold-hot emission balancing factor for WHR_ elec systems

In the case of an engine with a WHR_ elec system, the input data shall be the two values for specific E_WHR_net over the hotstart and coldstart WHTC in kJ/kWh determined in accordance with point 5.5.2.2.

The values shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06 and shall be the input under the respective fields in the tab 'WHR Electrical' in the GUI.

6.1.26 WHR correction factor for engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis

The input data shall be the correction factor determined in accordance with point 5.5.3.

The value shall be rounded to 2 places to the right of the decimal point in accordance with ASTM E 29-06 and shall be the input under the respective field in the tab 'WHR Electrical' for an engine with a WHR_ elec system and in the tab 'WHR Mechanical' for an engine with a WHR_mech system in the GUI.

▼B

Appendix 1

MODEL OF A CERTIFICATE OF A COMPONENT, SEPARATE TECHNICAL UNIT OR SYSTEM

Maximum format: A4 (210 × 297 mm)

CERTIFICATE ON CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF AN ENGINE FAMILY

Administration stamp

Communication concerning:

— granting (1)

— extension (1)

— refusal (1)

— withdrawal (1)

of a certificate on CO_2 emission and fuel consumption related properties of an engine family in accordance with Commission Regulation (EU) 2017/2400.

Commission Regulation (EU) 2017/2400 as last amended by ....

Certification number:

Hash:

Reason for extension:

SECTION I

0.1. Make (trade name of manufacturer):

0.2. Type:

0.3. Means of identification of type

0.3.1. Location of the certification marking:

0.3.2 Method of affixing certification marking:

0.5. Name and address of manufacturer:

0.6. Name(s) and address(es) of assembly plant(s):

0.7. Name and address of the manufacturer's representative (if any)

SECTION II

1. Additional information (where applicable): see Addendum

2. Approval authority responsible for carrying out the tests:

3. Date of test report:

4. Number of test report:

5. Remarks (if any): see Addendum

6. Place:

7. Date:

8. Signature:

Attachments:

Information package. Test report.

▼B

Appendix 2

Engine Information Document

Notes regarding filling in the tables:

Letters A, B, C, D, E corresponding to engine CO_2-family members shall be replaced by the actual engine CO_2-family members' names.

In case when for a certain engine characteristic same value/description applies for all engine CO_2-family members the cells corresponding to A-E shall be merged.

In case the engine CO_2-family consists of more than 5 members, new columns may be added.

The 'Appendix to information document' shall be copied and filled in for each engine within an CO_2-family separately.

Explanatory footnotes can be found at the very end of this Appendix.

		CO_2-parent engine	Engine CO_2-family members				
			A	B	C	D	E
0.	General						
0.1.	Make (trade name of manufacturer)						
0.2.	Type						
0.2.1.	Commercial name(s) (if available)						
0.5.	Name and address of manufacturer						
0.8.	Name(s) and address (es) of assembly plant(s)						
0.9.	Name and address of the manufacturer's representative (if any)						

PART 1

Essential characteristics of the (parent) engine and the engine types within an engine family

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.	Internal combustion engine						
3.2.1.	Specific engine information						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.1.1.	Working principle: positive ignition/compression ignition (1) Cycle four stroke/two stroke/ rotary (1)						

▼M3

		Parent engine or engine type	A	B	C	D	E
3.2.1.1.1.	Type of dual-fuel engine: Type 1A/Type 1B/Type 2A/Type 2B/Type 3B[1]						
3.2.1.1.2.	Gas Energy Ratio over the hot part of the WHTC: %						

▼B

		Parent engine or engine type	A	B	C	D	E
3.2.1.2.	Number and arrangement of cylinders						
3.2.1.2.1.	Bore (3) mm						
3.2.1.2.2.	Stroke (3) mm						
3.2.1.2.3.	Firing order						
3.2.1.3.	Engine capacity (4) cm^3						
3.2.1.4.	Volumetric compression ratio (5)						
3.2.1.5.	Drawings of combustion chamber, piston crown and, in the case of positive ignition engines, piston rings						
3.2.1.6.	Normal engine idling speed (5) min^{-1}						
3.2.1.6.1.	High engine idling speed (5) min^{-1}						

▼M3

		Parent engine or engine type	A	B	C	D	E
3.2.1.6.2.	Idle on Diesel: yes/no[1]						

▼B

		Parent engine or engine type	A	B	C	D	E
3.2.1.7.	Carbon monoxide content by volume in the exhaust gas with the engine idling (5): % as stated by the manufacturer (positive ignition engines only)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.1.8.	Maximum net power (6) .... kW at .... min^{-1} (manufacturer's declared value)						
3.2.1.9.	Maximum permitted engine speed as prescribed by the manufacturer (min^{-1})						
3.2.1.10.	Maximum net torque (6) .. (Nm) at .. (min^{-1}) (manufacturer's declared value)						
▼M3 3.2.1.11.	Manufacturer references of the documentation package required by paragraphs 3.1, 3.2 and 3.3 of UN Regulation No. 49 enabling the Type Approval Authority to evaluate the emission control strategies and the systems on-board the engine to ensure the correct operation of NO_x control measures						
▼B 3.2.2.	Fuel						
▼M1 3.2.2.2.	Heavy duty vehicles Diesel/Petrol/LPG/NG/Ethanol (ED95)/Ethanol (E85) (1)						
▼M3 3.2.2.2.1.	Fuels compatible with use by the engine declared by the manufacturer in accordance with paragraph 4.6.2 of UN Regulation No. 49 (as applicable)						

▼B

3.2.4.	Fuel feed						
▼M3 3.2.4.2.	By fuel injection (only compression ignition or dual-fuel): Yes/No (1)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.4.2.1.	System description						
3.2.4.2.2.	Working principle: direct injection/pre-chamber/swirl chamber ([1])						
3.2.4.2.3.	Injection pump						
3.2.4.2.3.1.	Make(s)						
3.2.4.2.3.2.	Type(s)						
3.2.4.2.3.3.	Maximum fuel delivery ([1]) ([5]) .... mm^3 /stroke or cycle at an engine speed of .... min^{-1} or, alternatively, a characteristic diagram (When boost control is supplied, state the characteristic fuel delivery and boost pressure versus engine speed)						
3.2.4.2.3.4.	Static injection timing ([5])						
3.2.4.2.3.5.	Injection advance curve ([5])						
3.2.4.2.3.6.	Calibration procedure: test bench/engine ([1])						
3.2.4.2.4.	Governor						
3.2.4.2.4.1.	Type						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.4.2.4.2.	Cut-off point						
3.2.4.2.4.2.1.	Speed at which cut-off starts under load (min^{-1})						
3.2.4.2.4.2.2.	Maximum no-load speed (min^{-1})						
3.2.4.2.4.2.3.	Idling speed (min^{-1})						
3.2.4.2.5.	Injection piping						
3.2.4.2.5.1.	Length (mm)						
3.2.4.2.5.2.	Internal diameter (mm)						
3.2.4.2.5.3.	Common rail, make and type						
3.2.4.2.6.	Injector(s)						
3.2.4.2.6.1.	Make(s)						
3.2.4.2.6.2.	Type(s)						
3.2.4.2.6.3.	Opening pressure ([5]): kPa or characteristic diagram ([5])						
3.2.4.2.7.	Cold start system						
3.2.4.2.7.1.	Make(s)						
3.2.4.2.7.2.	Type(s)						
3.2.4.2.7.3.	Description						
3.2.4.2.8.	Auxiliary starting aid						
3.2.4.2.8.1.	Make(s)						
3.2.4.2.8.2.	Type(s)						
3.2.4.2.8.3.	System description						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.4.2.9.	Electronic controlled injection: Yes/No ([1])						
3.2.4.2.9.1.	Make(s)						
3.2.4.2.9.2.	Type(s)						
3.2.4.2.9.3.	Description of the system (in the case of systems other than continuous injection give equivalent details)						
3.2.4.2.9.3.1.	Make and type of the control unit (ECU)						
3.2.4.2.9.3.2.	Make and type of the fuel regulator						
3.2.4.2.9.3.3.	Make and type of the air-flow sensor						
3.2.4.2.9.3.4.	Make and type of fuel distributor						
3.2.4.2.9.3.5.	Make and type of the throttle housing						
3.2.4.2.9.3.6.	Make and type of water temperature sensor						
3.2.4.2.9.3.7.	Make and type of air temperature sensor						
3.2.4.2.9.3.8.	Make and type of air pressure sensor						
3.2.4.2.9.3.9.	Software calibration number(s)						
3.2.4.3.	By fuel injection (positive ignition only): Yes/No ([1])						
3.2.4.3.1.	Working principle: intake manifold (single-/multi-point/direct injection ([1])/other specify)						
3.2.4.3.2.	Make(s)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.4.3.3.	Type(s)						
3.2.4.3.4.	System description (In the case of systems other than continuous injection give equivalent details)						
3.2.4.3.4.1.	Make and type of the control unit (ECU)						
3.2.4.3.4.2.	Make and type of fuel regulator						
3.2.4.3.4.3.	Make and type of air-flow sensor						
3.2.4.3.4.4.	Make and type of fuel distributor						
3.2.4.3.4.5.	Make and type of pressure regulator						
3.2.4.3.4.6.	Make and type of micro switch						
3.2.4.3.4.7.	Make and type of idling adjustment screw						
3.2.4.3.4.8.	Make and type of throttle housing						
3.2.4.3.4.9.	Make and type of water temperature sensor						
3.2.4.3.4.10.	Make and type of air temperature sensor						
3.2.4.3.4.11.	Make and type of air pressure sensor						
3.2.4.3.4.12.	Software calibration number(s)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.4.3.5.	Injectors: opening pressure (5) (kPa) or characteristic diagram (5)						
3.2.4.3.5.1.	Make						
3.2.4.3.5.2.	Type						
3.2.4.3.6.	Injection timing						
3.2.4.3.7.	Cold start system						
3.2.4.3.7.1.	Operating principle(s)						
3.2.4.3.7.2.	Operating limits/settings (1) (5)						
3.2.4.4.	Feed pump						
3.2.4.4.1.	Pressure (5) (kPa) or characteristic diagram (5)						
3.2.5.	Electrical system						
3.2.5.1.	Rated voltage (V), positive/negative ground (1)						
3.2.5.2.	Generator						
3.2.5.2.1.	Type						
3.2.5.2.2.	Nominal output (VA)						
3.2.6.	Ignition system (spark ignition engines only)						
3.2.6.1.	Make(s)						
3.2.6.2.	Type(s)						
3.2.6.3.	Working principle						
3.2.6.4.	Ignition advance curve or map (5)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.6.5.	Static ignition timing (5) (degrees before TDC)						
3.2.6.6.	Spark plugs						
3.2.6.6.1.	Make						
3.2.6.6.2.	Type						
3.2.6.6.3.	Gap setting (mm)						
3.2.6.7.	Ignition coil(s)						
3.2.6.7.1.	Make						
3.2.6.7.2.	Type						
3.2.7.	Cooling system: liquid/air (1)						
3.2.7.2.	Liquid						
3.2.7.2.1.	Nature of liquid						
3.2.7.2.2.	Circulating pump(s): Yes/No (1)						
3.2.7.2.3.	Characteristics						
3.2.7.2.3.1.	Make(s)						
3.2.7.2.3.2.	Type(s)						
3.2.7.2.4.	Drive ratio(s)						
3.2.7.3.	Air						
3.2.7.3.1.	Fan: Yes/No (1)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.7.3.2.	Characteristics						
3.2.7.3.2.1.	Make(s)						
3.2.7.3.2.2.	Type(s)						
3.2.7.3.3.	Drive ratio(s)						
3.2.8.	Intake system						
3.2.8.1.	Pressure charger: Yes/No ([1])						
3.2.8.1.1.	Make(s)						
3.2.8.1.2.	Type(s)						
3.2.8.1.3.	Description of the system (e.g. maximum charge pressure ... kPa, wastegate, if applicable)						
3.2.8.2.	Intercooler: Yes/No ([1])						
3.2.8.2.1.	Type: air-air/air-water ([1])						
3.2.8.3.	Intake depression at rated engine speed and at 100 % load (compression ignition engines only)						
3.2.8.3.1.	Minimum allowable (kPa)						
3.2.8.3.2.	Maximum allowable (kPa)						
3.2.8.4.	Description and drawings of inlet pipes and their accessories (plenum chamber, heating device, additional air intakes, etc.)						
3.2.8.4.1.	Intake manifold description (include drawings and/or photos)						
3.2.9.	Exhaust system						
3.2.9.1.	Description and/or drawings of the exhaust manifold						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.9.2.	Description and/or drawing of the exhaust system						
3.2.9.2.1.	Description and/or drawing of the elements of the exhaust system that are part of the engine system						
3.2.9.3.	Maximum allowable exhaust back pressure at rated engine speed and at 100 % load (compression ignition engines only)(kPa) ([7])						
3.2.9.7.	Exhaust system volume (dm^3)						
3.2.9.7.1.	Acceptable Exhaust system volume: (dm^3)						
3.2.10.	Minimum cross-sectional areas of inlet and outlet ports and port geometry						
3.2.11.	Valve timing or equivalent data						
3.2.11.1.	Maximum lift of valves, angles of opening and closing, or timing details of alternative distribution systems, in relation to dead centers. For variable timing system, minimum and maximum timing						
3.2.11.2.	Reference and/or setting range ([7])						
3.2.12.	Measures taken against air pollution						
▼M3 3.2.12.1.1.	Device for recycling crankcase gases: Yes/No ([1]) If yes, description and drawings If no, compliance with paragraph 6.10 of Annex 4 to UN Regulation No. 49 required						
▼B 3.2.12.2.	Additional pollution control devices (if any, and if not covered by another heading)						
3.2.12.2.1.	Catalytic converter: Yes/No ([1])						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.12.2.1.1.	Number of catalytic converters and elements (provide this information below for each separate unit)						
3.2.12.2.1.2.	Dimensions, shape and volume of the catalytic converter(s)						
3.2.12.2.1.3.	Type of catalytic action						
3.2.12.2.1.4.	Total charge of precious metals						
3.2.12.2.1.5.	Relative concentration						
3.2.12.2.1.6.	Substrate (structure and material)						
3.2.12.2.1.7.	Cell density						
3.2.12.2.1.8.	Type of casing for the catalytic converter(s)						
3.2.12.2.1.9.	Location of the catalytic converter(s) (place and reference distance in the exhaust line)						
3.2.12.2.1.10.	Heat shield: Yes/No ([1])						
3.2.12.2.1.11.	Regeneration systems/method of exhaust after treatment systems, description						
3.2.12.2.1.11.5.	Normal operating temperature range (K)						
3.2.12.2.1.11.6.	Consumable reagents: Yes/No ([1])						
3.2.12.2.1.11.7.	Type and concentration of reagent needed for catalytic action						
3.2.12.2.1.11.8.	Normal operational temperature range of reagent K						
3.2.12.2.1.11.9.	International standard						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.12.2.1.11.10.	Frequency of reagent refill: continuous/maintenance ([1])						
3.2.12.2.1.12.	Make of catalytic converter						
3.2.12.2.1.13.	Identifying part number						
3.2.12.2.2.	Oxygen sensor: Yes/No ([1])						
3.2.12.2.2.1.	Make						
3.2.12.2.2.2.	Location						
3.2.12.2.2.3.	Control range						
3.2.12.2.2.4.	Type						
3.2.12.2.2.5.	Indentifying part number						
3.2.12.2.3.	Air injection: Yes/No ([1])						
3.2.12.2.3.1.	Type (pulse air, air pump, etc.)						
3.2.12.2.4.	Exhaust gas recirculation (EGR): Yes/No ([1])						
3.2.12.2.4.1.	Characteristics (make, type, flow, etc)						
3.2.12.2.6.	Particulate trap (PT): Yes/No ([1])						
3.2.12.2.6.1.	Dimensions, shape and capacity of the particulate trap						
3.2.12.2.6.2.	Design of the particulate trap						
3.2.12.2.6.3.	Location (reference distance in the exhaust line)						
3.2.12.2.6.4.	Method or system of regeneration, description and/or drawing						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.12.2.6.5.	Make of particulate trap						
3.2.12.2.6.6.	Indentifying part number						
3.2.12.2.6.7.	Normal operating temperature (K) and pressure (kPa) ranges						
3.2.12.2.6.8.	In the case of periodic regeneration						
3.2.12.2.6.8.1.1.	Number of WHTC test cycles without regeneration (n)						
3.2.12.2.6.8.2.1.	Number of WHTC test cycles with regeneration (n_R)						
3.2.12.2.6.9.	Other systems: Yes/No ([1])						
3.2.12.2.6.9.1.	Description and operation						
▼M3 3.2.12.2.7.	If applicable, manufacturer's reference to the documentation for installing the dual-fuel engine in a vehicle						
———							
3.2.17.	Specific information related to gas fuelled engines and dual-fuel engines for heavy-duty vehicles (in the case of systems laid out in a different manner, supply equivalent information)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.17.1.	Fuel: LPG /NG-H/NG-L /NG-HL ([1])						
3.2.17.2.	Pressure regulator(s) or vaporiser/pressure regulator(s) ([1])						
3.2.17.2.1.	Make(s)						
3.2.17.2.2.	Type(s)						
3.2.17.2.3.	Number of pressure reduction stages						
3.2.17.2.4.	Pressure in final stage minimum (kPa) – maximum. (kPa)						
3.2.17.2.5.	Number of main adjustment points						
3.2.17.2.6.	Number of idle adjustment points						
3.2.17.2.7.	Type approval number						
3.2.17.3.	Fuelling system: mixing unit / gas injection / liquid injection / direct injection ([1])						
3.2.17.3.1.	Mixture strength regulation						
3.2.17.3.2.	System description and/or diagram and drawings						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.17.3.3.	Type approval number						
3.2.17.4.	Mixing unit						
3.2.17.4.1.	Number						
3.2.17.4.2.	Make(s)						
3.2.17.4.3.	Type(s)						
3.2.17.4.4.	Location						
3.2.17.4.5.	Adjustment possibilities						
3.2.17.4.6.	Type approval number						
3.2.17.5.	Inlet manifold injection						
3.2.17.5.1.	Injection: single point/multipoint ([1])						
3.2.17.5.2.	Injection: continuous/simultaneously timed/sequentially timed ([1])						
3.2.17.5.3.	Injection equipment						
3.2.17.5.3.1.	Make(s)						
3.2.17.5.3.2.	Type(s)						
3.2.17.5.3.3.	Adjustment possibilities						
3.2.17.5.3.4.	Type approval number						
3.2.17.5.4.	Supply pump (if applicable)						
3.2.17.5.4.1.	Make(s)						
3.2.17.5.4.2.	Type(s)						
3.2.17.5.4.3.	Type approval number						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.17.5.5.	Injector(s)						
3.2.17.5.5.1.	Make(s)						
3.2.17.5.5.2.	Type(s)						
3.2.17.5.5.3.	Type approval number						
3.2.17.6.	Direct injection						
3.2.17.6.1.	Injection pump/pressure regulator ([1])						
3.2.17.6.1.1.	Make(s)						
3.2.17.6.1.2.	Type(s)						
3.2.17.6.1.3.	Injection timing						
3.2.17.6.1.4.	Type approval number						
3.2.17.6.2.	Injector(s)						
3.2.17.6.2.1.	Make(s)						
3.2.17.6.2.2.	Type(s)						
3.2.17.6.2.3.	Opening pressure or characteristic diagram ([1])						
3.2.17.6.2.4.	Type approval number						
3.2.17.7.	Electronic control unit (ECU)						
3.2.17.7.1.	Make(s)						
3.2.17.7.2.	Type(s)						
3.2.17.7.3.	Adjustment possibilities						
3.2.17.7.4.	Software calibration number(s)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.2.17.8.	NG fuel-specific equipment						
3.2.17.8.1.	Variant 1 (only in the case of approvals of engines for several specific fuel compositions)						
3.2.17.8.1.0.1.	Self-adaptive feature? Yes/No (1)						
▼M1 __________							
▼B 3.2.17.8.1.1.	methane (CH_4) .... basis (%mole) min (%mole) max (%mole) ethane (C_2H_6) .... basis (%mole) min (%mole) max (%mole) propane (C_3H_8) .... basis (%mole) min (%mole) max (%mole) butane (C_4H_{10}) .... basis (%mole) min (%mole) max (%mole) C_5/C_{5+}: .... basis (%mole) min (%mole) max (%mole) oxygen (O_2) .... basis (%mole) min (%mole) max (%mole) inert (N_2, He etc) .... basis (%mole) min (%mole) max (%mole)						
▼M3 3.5.5.	Specific fuel consumption, specific CO_2 emissions and correction factors						
▼B 3.5.5.1.	Specific fuel consumption over WHSC 'SFC_{WHSC}' in accordance with paragraph 5.3.3 g/kWh ►M3 (9) ◄						
3.5.5.2.	Corrected specific fuel consumption over WHSC 'SFC_{WHSC}, corr' in accordance with paragraph 5.3.3.1: … g/kWh ►M3 (9) ◄						
▼M3 3.5.5.2.1.	For dual-fuel engines: Specific CO_2 emissions over the WHSC in accordance with point 6.1 of Appendix 4 g/kWh (9)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.5.5.3.	Correction factor for WHTC urban part (from output of engine pre-processing tool) ►**M3** (9) ◄						
3.5.5.4.	Correction factor for WHTC rural part (from output of engine pre-processing tool) ►**M3** (9) ◄						
3.5.5.5.	Correction factor for WHTC motorway part (from output of engine pre-processing tool) ►**M3** (9) ◄						
3.5.5.6.	Cold-hot emission balancing factor (from output of engine pre-processing tool) ►**M3** (9) ◄						
3.5.5.7.	Correction factor for engines equipped with exhaust after-treatment systems that are regenerated on a periodic basis CF_{RegPer} (from output of engine pre-processing tool) ►**M3** (9) ◄						
3.5.5.8.	Correction factor to standard NCV (from output of engine pre-processing tool) ►**M3** (9) ◄						
3.6.	Temperatures permitted by the manufacturer						
3.6.1.	Cooling system						
3.6.1.1.	Liquid cooling Maximum temperature at outlet (K)						
3.6.1.2.	Air cooling						
3.6.1.2.1.	Reference point						
3.6.1.2.2.	Maximum temperature at reference point (K)						
3.6.2.	Maximum outlet temperature of the inlet intercooler (K)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.6.3.	Maximum exhaust temperature at the point in the exhaust pipe(s) adjacent to the outer flange(s) of the exhaust manifold(s) or turbocharger(s) (K)						
3.6.4.	Fuel temperature Minimum (K) – maximum (K) For diesel engines at injection pump inlet, for gas fuelled engines at pressure regulator final stage						
3.6.5.	Lubricant temperature Minimum (K) – maximum (K)						

3.8.	Lubrication system						
3.8.1.	Description of the system						
3.8.1.1.	Position of lubricant reservoir						
3.8.1.2.	Feed system (by pump/injection into intake/mixing with fuel, etc.) ([1])						
3.8.2.	Lubricating pump						
3.8.2.1.	Make(s)						
3.8.2.2.	Type(s)						
3.8.3.	Mixture with fuel						
3.8.3.1.	Percentage						
3.8.4.	Oil cooler: Yes/No ([1])						
3.8.4.1.	Drawing(s)						

▼B

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.8.4.1.1.	Make(s)						
3.8.4.1.2.	Type(s)						

▼M3

3.9	WHR System						
3.9.1	Type of WHR system: WHR_no_ext, WHR_mech, WHR_elec						
3.9.2	Operation principle						
3.9.3	Description of the system						
3.9.4	Evaporator type ([10])						
3.9.5	L_{EW} in accordance with 3.1.6.2(a)						
3.9.6	$Lmax_{EW}$ in accordance with 3.1.6.2(a)						
3.9.7	Turbine type						
3.9.8	L_{ET} in accordance with 3.1.6.2(b)						
3.9.9	$Lmax_{ET}$ in accordance with 3.1.6.2(b)						
3.9.10	Expander type						
3.9.11	L_{HE} in accordance with 3.1.6.2(c)(i)						
3.9.12	$Lmax_{HE}$ in accordance with 3.1.6.2(c)(i)						
3.9.13	Condenser type						
3.9.14	L_{EC} in accordance with 3.1.6.2(c)(ii)						
3.9.15	$Lmax_{EC}$ in accordance with 3.1.6.2(c)(ii)						
3.9.16	L_{CE} in accordance with 3.1.6.2(c)(iii)						

▼ M3

		Parent engine or engine type	Engine CO_2-family members				
			A	B	C	D	E
3.9.17	$Lmax_{CE}$ in accordance with 3.1.6.2(c)(iii)						
3.9.18	Rotational speed at which the net mechanical power was measured for WHR_mech systems in accordance with 3.1.6.2(f)						

▼ B

Notes:

(1) Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable).

(3) This figure shall be rounded off to the nearest tenth of a millimetre.

(4) This value shall be calculated and rounded off to the nearest cm^3.

(5) Specify the tolerance.

(6) Determined in accordance with the requirements of Regulation No. 85.

(7) Please fill in here the upper and lower values for each variant.

(8) To be documented in case of a single OBD engine family and if not already documented in the documentation package(s) referred to in line 3.2.12.2.7.0.4. of Part 1 of this Appendix.

▼ M3

(9) For dual-fuel engines indicate values for each fuel type and each operation mode separately.

(10) For other WHR systems this shall reflect the heat exchanger type in accordance with 3.1.6.2(d).

▼B

Appendix to information document

Information on test conditions

1. Spark plugs

1.1. Make

1.2. Type

1.3. Spark-gap setting

2. Ignition coil

2.1. Make

2.2. Type

3. Lubricant used

3.1. Make

3.2. Type (state percentage of oil in mixture if lubricant and fuel mixed)

3.3. Specifications of lubricant

▼M3

4. Test fuel used [1]

▼B

4.1. Fuel type (in accordance with paragraph 6.1.9 of Annex V to Commission Regulation (EU) 2017/2400)

4.2. Unique identification number (production batch number) of fuel used

4.3. Net calorific value (NCV) (in accordance with paragraph 6.1.8 of Annex V to Commission Regulation (EU) 2017/2400)

▼M1

4.4. Reference fuel type (type of reference fuel used for testing in accordance with point 3.2 of Annex V to Commission Regulation (EU) 2017/2400)

▼B

5. Engine-driven equipment

5.1. The power absorbed by the auxiliaries/equipment needs only be determined,

(a) If auxiliaries/equipment required are not fitted to the engine and/or

(b) If auxiliaries/equipment not required are fitted to the engine.

Note: Requirements for engine-driven equipment differ between emissions test and power test

5.2. Enumeration and identifying details

5.3. Power absorbed at engine speeds specific for emissions test

[1] For dual-fuel engines indicate values for each fuel type and each operation mode separately;

▼B

Table 1

Power absorbed at engine speeds specific for emissions test

Equipment					
	Idle	Low speed	High speed	Preferred speed ([2])	n_{95h}
P_a Auxiliaries/equipment required according to Annex 4, Appendix 6 of ►M3 UN Regulation No. 49 ◄					
P_b Auxiliaries/equipment not required according to Annex 4, Appendix 6 of ►M3 UN Regulation No. 49 ◄					

5.4. Fan constant determined in accordance with Appendix 5 to this Annex (if applicable)

5.4.1. $C_{avg\text{-}fan}$ (if applicable)

5.4.2. $C_{ind\text{-}fan}$ (if applicable)

Table 2

Value of fan constant $C_{ind\text{-}fan}$ for different engine speeds

Value	Engine speed 1	Engine speed 2	Engine speed 3	Engine speed 4	Engine speed 5	Engine speed 6	Engine speed 7	Engine speed 8	Engine speed 9	Engine speed 10
engine speed [min^{-1}]										
fan constant $C_{ind\text{-}fan,i}$										

6. Engine performance (declared by manufacturer)

6.1. ►M3 Engine test speeds for emissions test (for dual-fuel engines performed in dual-fuel mode) in accordance with Annex 4 to UN Regulation No. 49 ([1]) ◄

Low speed (nlo) .... min^{-1}

High speed (nhi) .... min^{-1}

Idle speed .... min^{-1}

Preferred speed .... min^{-1}

n_{95h} .... min^{-1}

([1]) Specify the tolerance; to be within ± 3 % of the values declared by the manufacturer.

▼**M3**

6.2. Declared values for power test (for dual-fuel engines performed in dual-fuel mode) in accordance with UN Regulation No. 85 ([1])

▼**B**

6.2.1. Idle speed .... min^{-1}

6.2.2. Speed at maximum power .... min^{-1}

6.2.3. Maximum power .... kW

6.2.4. Speed at maximum torque .... min^{-1}

6.2.5. Maximum torque .... Nm

([1]) Regulation No 85 of the Economic Commission for Europe of the United Nations (UN/ECE) – Uniform provisions concerning the approval of internal combustion engines or electric drive trains intended for the propulsion of motor vehicles of categories M and N with regard to the measurement of net power and the maximum 30 minutes power of electric drive trains (OJ L 323, 7.11.2014, p. 52)

▼B

Appendix 3

Engine CO_2-Family

▼M3

1. Parameters defining the engine CO_2-family

The engine CO_2-family, as determined by the manufacturer, shall comply with the membership criteria defined in accordance with paragraph 5.2.3 of Annex 4 to UN Regulation No. 49. An engine CO_2-family may consist of only one engine.

In the case of a dual-fuel engine, the engine CO_2-family shall also comply with the additional requirements of paragraph 3.1.1 of Annex 15 to UN Regulation No. 49.

In addition to those membership criteria, the engine CO_2-family, as determined by the manufacturer, shall comply with the membership criteria listed in points 1.1 to 1.10.

In addition to the parameters listed in points 1.1 to 1.10, the manufacturer may introduce additional criteria allowing the definition of families of more restricted size. These parameters are not necessarily parameters that have an influence on the level of fuel consumption.

▼B

1.1. Combustion relevant geometric data

1.1.1. Displacement per cylinder

1.1.2. Number of cylinders

1.1.3. Bore and stroke data

1.1.4. Combustion chamber geometry and compression ratio

1.1.5. Valve diameters and port geometry

1.1.6. Fuel injectors (design and position)

1.1.7. Cylinder head design

1.1.8. Piston and piston ring design

1.2. Air management relevant components

1.2.1. Pressure charging equipment type (waste gate, VTG, 2-stage, other) and thermodynamic characteristics

1.2.2. Charge air cooling concept

1.2.3. Valve timing concept (fixed, partly flexible, flexible)

1.2.4. EGR concept (uncooled/cooled, high/low pressure, EGR-control)

1.3. Injection system

▼B

1.4. Auxiliary/equipment propulsion concept (mechanically, electrically, other)

▼M3

1.5. Waste heat recovery system(s)

1.5.1. Type of WHR system(s) (defined in accordance with point 2 of this Annex)

1.5.2. Setup of WHR system for testing in accordance with point 3.1.6 of this Annex

1.5.3. Type of turbine of WHR system(s)

1.5.4. Type of evaporator of WHR system(s)

1.5.5. Type of expander of WHR system(s)

1.5.6. Type of condenser of WHR system(s)

1.5.7. Type of pump of WHR system(s)

1.5.8. L_{EW} in accordance with 3.1.6.2(a) of this Annex for all other engines within the same CO_2-family shall be equal or higher than for the CO_2-parent engine

1.5.9. L_{ET} in accordance with 3.1.6.2(b) of this Annex for all other engines within the same CO_2-family shall be equal or higher than for the CO_2-parent engine

1.5.10. L_{HE} in accordance with 3.1.6.2(c)(i) of this Annex for all other engines within the same CO_2-family shall be equal or higher than for the CO_2-parent engine

1.5.11. L_{EC} in accordance with 3.1.6.2(c)(ii) of this Annex for all other engines within the same CO_2-family shall be equal or smaller than for the CO_2-parent engine

1.5.12. L_{CE} in accordance with 3.1.6.2(c)(iii) of this Annex for all other engines within the same CO_2-family shall be equal or smaller than for the CO_2-parent engine

1.5.13. p_{cond} in accordance with 3.1.6.2(c)(iv) of this Annex for all other engines within the same CO_2-family shall be equal or higher than for the CO_2-parent engine

1.5.14. P_{cool} in accordance with 3.1.6.2(c)(v) of this Annex for all other engines within the same CO_2-family shall be equal or higher than for the CO_2-parent engine

▼B

1.6. Aftertreatment system

1.6.1. Reagent dosing system characteristics (reagent and dosing concept)

1.6.2. Catalyst and DPF (arrangement, material and coating)

1.6.3. HC dosing system characteristics (design and dosing concept)

▼B

1.7. Full load curve

1.7.1. The torque values at each engine speed of the full load curve of the CO_2-parent engine determined in accordance with paragraph 4.3.1. shall be equal or higher than for all other engine within the same CO_2-family at the same engine speed over the whole engine speed range recorded.

1.7.2. The torque values at each engine speed of the full load curve of the engine with the lowest power rating of all engines within the engine CO_2-family determined in accordance with paragraph 4.3.1. shall be equal or lower than for all other engines within the same CO_2-family at the same engine speed over the whole engine speed range recorded.

▼M3

1.7.3. Torque values within a tolerance band related to the reference described in points 1.7.1 and 1.7.2 are considered as equal. The tolerance band is defined as + 40 Nm or + 4 % of the CO_2 parent engine torque at the particular engine speed, whichever is greater.

▼B

1.8. Characteristic engine test speeds

▼M1

1.8.1. The engine idle speed, n_{idle}, of the CO_2-parent engine as declared by the manufacturer at the application for certification in the information document in accordance with point 3.2.1.6 of Appendix 2 to this Annex shall be equal or lower than for all other engines within the same CO_2-family.

▼B

1.8.2. The engine speed n_{95h} of all other engines than the CO_2-parent engine within the same CO_2-family, determined from the engine full load curve recorded in accordance with paragraph 4.3.1 by applying the definitions of characteristic engine speeds in accordance with paragraph 7.4.6. of Annex 4 to ►M3 UN Regulation No. 49 ◄, shall not deviate from the engine speed n_{95h} of the CO_2-parent engine by more than ± 3 percent.

1.8.3. The engine speed n_{57} of all other engines than the CO_2-parent engine within the same CO_2-family, determined from the engine full load curve recorded in accordance with paragraph 4.3.1 by applying the definitions in accordance with paragraph 4.3.5.2.1, shall not deviate from the engine speed n_{57} of the CO_2-parent engine by more than ± 3 percent.

1.9. Minimum number of points in the fuel consumption map

1.9.1. All engines within the same CO_2-family shall have a minimum number of 54 mapping points of the fuel consumption map located below their respective engine full load curve determined in accordance with paragraph 4.3.1.

▼M3

1.10. Variation in GER_{WHTC}

▼**M3**

1.10.1. For dual-fuel engines, the difference between the highest and the lowest GER_{WHTC}

(i.e. the highest GER_{WHTC} minus the lowest GER_{WHTC}) within the same CO_2-family shall not exceed 10 %.

▼**B**

2. Choice of the CO_2-parent engine

The CO_2-parent engine of the engine CO_2-family shall be selected in accordance with the following criteria:

2.1. Highest power rating of all engines within the engine CO_2-family.

▼B

Appendix 4

Conformity of CO_2 emissions and fuel consumption related properties

1. General provisions

1.1 Conformity of CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificates set out in Appendix 1 to this Annex and on the basis of the description in the information document set out in Appendix 2 to this Annex.

1.2 If an engine certificate has had one or more extensions, the tests shall be carried out on the engines described in the information package relating to the relevant extension.

1.3 All engines subject to tests shall be taken from the series production meeting the selection criteria according to paragraph 3 of this Appendix.

1.4 The tests may be conducted with the applicable market fuels. However, at the manufacturer's request, the reference fuels specified in paragraph 3.2 may be used.

1.5 If tests for the purpose of conformity of CO_2 emissions and fuel consumption related properties of gas engines (natural gas, LPG) are conducted with market fuels the engine manufacturer shall demonstrate to the approval authority the appropriate determination of the gas fuel composition for the determination of the NCV according to paragraph 4 of this Appendix by good engineering judgement.

2. Number of engines and engine CO_2-families to be tested

2.1 0,05 percent of all engines produced in the past production year within the scope of this regulation shall represent the basis to derive the number of engine CO_2-families and number of engines within those CO_2-families to be tested annually for verifying conformity of the certified CO_2 emissions and fuel consumption related properties. The resulting figure of 0,05 percent of relevant engines shall be rounded to the nearest whole number. This result shall be called $n_{COP,base}$.

2.2 Notwithstanding the provisions in point 2.1, a minimum number of 30 shall be used for $n_{COP,base}$.

2.3 The resulting figure for $n_{COP,base}$ determined in accordance with points 2.1 and 2.2 of this Appendix shall be divided by 10 and the result rounded to the nearest whole number in order to determine the number of engine CO_2-families to be tested annually, $n_{COP,fam}$, for verifying conformity of the certified CO_2 emissions and fuel consumption related properties.

2.4 In the case that a manufacturer has less CO_2-families than $n_{COP,fam}$ determined in accordance with point 2.3, the number of CO_2-families to be tested, $n_{COP,fam}$, shall be defined by the total number of CO_2-families of the manufacturer.

3. Selection of engine CO_2-families to be tested

From the number of engine CO_2-families to be tested determined in accordance with paragraph 2 of this Appendix, the first two CO_2-families shall be those with the highest production volumes.

The remaining number of engine CO_2-families to be tested shall be randomly selected from all existing engine CO_2-families and shall be agreed between the manufacturer and the approval authority.

▼B

4. Testrun to be performed

▼M1

The minimum number of engines to be tested for each engine CO_2-family, $n_{COP,min}$, shall be determined by dividing $n_{COP,base}$ by $n_{COP,fam}$, both values determined in accordance with point 2. The result for $n_{COP,min}$ shall be rounded to the nearest integer. If the resulting value for $n_{COP,min}$ is smaller than 4 it shall be set to 4, if it is greater than 19 it shall be set to 19.

▼B

For each of the engine CO_2-families determined in accordance with paragraph 3 of this Appendix a minimum number of $n_{COP,min}$ engines within that family shall be tested in order to reach a pass decision in accordance with paragraph 9 of this Appendix.

The number of testruns to be performed within an engine CO_2-family shall be randomly assigned to the different engines within that CO_2-family and this assignment shall be agreed between the manufacturer and the approval authority.

Conformity of the certified CO_2 emissions and fuel consumption related properties shall be verified by testing the engines in the WHSC test in accordance with paragraph 4.3.4.

All boundary conditions as specified in this Annex for the certification testing shall apply, except for the following:

(1) The laboratory test conditions in accordance with paragraph 3.1.1 of this Annex. The conditions in accordance with paragraph 3.1.1 are recommended and shall not be mandatory. Deviations may occur under certain ambient conditions at the testing site and should be minimized by the use of good engineering judgment.

(2) In case reference fuel of the type B7 (Diesel / CI) in accordance with paragraph 3.2 of this Annex is used, the determination of the NCV in accordance with paragraph 3.2 of this Annex shall not be required.

(3) In case market fuel or reference fuel other than B7 (Diesel / CI) is used, the NCV of the fuel shall be determined in accordance with the applicable standards defined in Table 1 of this Annex. With exemption of gas engines the NCV measurement shall be performed by only one lab independent from the engine manufacturer instead of two as required in accordance with paragraph 3.2 of this Annex. ►M1 NCV for reference gas fuels (G_{25}/G_R, LPG fuel B) shall be calculated in accordance with the applicable standards in Table 1 of this Annex from the fuel analysis submitted by the reference gas fuel supplier. ◄

(4) The lubricating oil shall be the one filled during engine production and shall not be changed for the purpose of testing conformity of CO_2 emissions and fuel consumption related properties.

5. Run-in of newly manufactured engines

5.1 The tests shall be carried out on newly manufactured engines taken from the series production which have a maximum run-in time of 15 hours before the testrun for the verification of conformity of the certified CO_2 emissions and fuel consumption related properties in accordance with paragraph 4 of this Appendix is started.

5.2 At the request of the manufacturer, the tests may be carried out on engines which have been run-in up to a maximum of 125 hours. In this case, the running-in procedure shall be conducted by the manufacturer who shall not make any adjustments to those engines.

▼B

5.3 When the manufacturer requests to conduct a running-in procedure in accordance with point 5.2 of this Appendix it may be carried out on either of the following:

(a) all the engines that are tested

▼M3

(b) newly produced engine, with the determination of an evolution coefficient as follows:

A. The fuel consumption shall be measured over the WHSC test, performed in accordance with point 4 of this Appendix, once on the newly manufactured engine with a maximum run-in time of 15 hours in accordance with point 5.1 of this Appendix and in the second test before the maximum of 125 hours set in point 5.2 of this Appendix on the first engine tested.

B. The specific fuel consumption over the WHSC, SFC_{WHSC}, shall be determined in accordance with point 5.3.3 of this Annex from the values measured in point (A) of this point.

C. The values for the specific fuel consumption of both tests shall be adjusted to a corrected value in accordance with points 7.2, 7.3 and 7.4 of this Appendix for the respective fuel used during each of the two tests.

D. The evolution coefficient shall be calculated by dividing the corrected specific fuel consumption of the second test by the corrected specific fuel consumption of the first test. The evolution coefficient may have a value less than one.

E. For dual-fuel engines point D. above shall not apply. Instead, the evolution coefficient shall be calculated by dividing the specific CO_2 emissions of the second test by the specific CO_2 emissions of the first test. The two values for specific CO_2 emissions shall be determined in accordance with the provisions stated in point 6.1 of this Appendix using the two values of $SFC_{WHSC,corr}$ determined in accordance with sub-subpoint C. above. The evolution coefficient may have a value less than one.

5.4 If the provisions defined in point 5.3(b) of this Appendix are applied, the subsequent engines selected for testing of conformity of CO_2 emissions and fuel consumption related properties shall not be subjected to the running-in procedure, but their specific fuel consumption over the WHSC or specific CO_2 emissions over the WHSC in the case of dual-fuel engines determined on the newly manufactured engine with a maximum run-in time of 15 hours in accordance with point 5.1 of this Appendix shall be multiplied by the evolution coefficient.

5.5 In the case described in point 5.4 of this Appendix the values for the specific fuel consumption over the WHSC or specific CO_2 emissions over the WHSC in the case of dual-fuel engines to be taken shall be the following:

(a) for the engine used for determination of the evolution coefficient in accordance with point 5.3 (b) of this Appendix, the value from the second test

▼M3

(b) for the other engines, the values determined on the newly manufactured engine with a maximum run-in time of 15 hours in accordance with point 5.1 of this Appendix multiplied by the evolution coefficient determined in accordance with point 5.3 (b)(D) of this Appendix or point 5.3 (b)(E) of this Appendix in the case of dual-fuel engines.

5.6 Instead of using a running-in procedure in accordance with points 5.2 to 5.5 of this Appendix, a generic evolution coefficient of 0,99 may be used at the request of the manufacturer. In this case the specific fuel consumption over the WHSC or specific CO_2 emissions over the WHSC in the case of dual-fuel engines determined on the newly manufactured engine with a maximum run-in time of 15 hours in accordance with point 5.1 of this Appendix shall be multiplied by the generic evolution coefficient of 0,99.

▼B

5.7 If the evolution coefficient in accordance with point 5.3 (b) of this Appendix is determined using the parent engine of an engine family according to paragraphs 5.2.3. and 5.2.4. of Annex 4 to Regulation ►M3 UN Regulation No. 49 ◄, it may be carried across to all members of any CO_2-family belonging to the same engine family according to paragraph 5.2.3. of Annex 4 to Regulation ►M3 UN Regulation No. 49 ◄.

6. Target value for assessment of conformity of the certified CO_2 emissions and fuel consumption related properties

The target value to assess the conformity of the certified CO_2 emissions and fuel consumption related properties shall be the corrected specific fuel consumption over the WHSC, $SFC_{WHSC,corr}$, in g/kWh determined in accordance with paragraph 5.3.3 and documented in the information document as part of the certificates set out in Appendix 2 to this Annex for the specific engine tested.

▼M3

6.1 Special requirements for dual-fuel engines

For dual-fuel engines, the target value to assess the conformity of the certified CO_2 emissions and fuel consumption related properties shall be calculated from the two separate values for each fuel of the corrected specific fuel consumption over the WHSC, $SFC_{WHSC,corr}$, in g/kWh determined in accordance with point 5.3.3. Each of the two separate values for each fuel shall be multiplied by the respective CO_2 emission factor for each fuel in accordance with Table 1 of this Appendix. The sum of the two resulting values of specific CO_2 emissions over the WHSC defines the applicable target value to assess the conformity of the certified CO_2 emissions and fuel consumption related properties of dual-fuel engines.

Table 1

CO_2 emission factors of fuel types

Fuel type / engine type	Reference fuel type	CO_2 emission factors [g CO_2/g fuel]
Diesel / CI	B7	3,13
LPG / PI	LPG Fuel B	3,02
Natural Gas / PI or Natural Gas / CI	G_{25} or G_R	2,73

▼B

7. Actual value for assessment of conformity of the certified CO_2 emissions and fuel consumption related properties

7.1 The specific fuel consumption over the WHSC, SFC_{WHSC}, shall be determined in accordance with paragraph 5.3.3 of this Annex from the testruns performed in accordance with paragraph 4 of this Appendix. At the request of the manufacturer the specific fuel consumption value determined shall be modified by applying the provisions defined in points 5.3 to 5.6 of this Appendix.

7.2 If market fuel was used during testing in accordance with point 1.4 of this Appendix, the specific fuel consumption over the WHSC, SFC_{WHSC}, determined in point 7.1 of this Appendix shall be adjusted to a corrected value, $SFC_{WHSC,corr}$, in accordance with paragraph 5.3.3.1 of this Annex.

▼M3

7.3 If reference fuel was used during testing in accordance with point 1.4 of this Appendix the special provisions defined in point 5.3.3.2 of this Annex shall be applied to the value determined in point 7.1 of this Appendix to calculate the corrected value, $SFC_{WHSC,corr}$.

7.3.a For dual-fuel engines the special provisions defined in point 5.3.3.3 of this Annex shall be applied in addition to points 7.2 and 7.3 to the value determined in point 7.1 of this Appendix to calculate the corrected value, $SFC_{WHSC,corr}$.

▼B

7.4 The measured emission of gaseous pollutants over the WHSC performed in accordance with paragraph 4 shall be adjusted by application of the appropriate deterioration factors (DF's) for that engine as recorded in the Addendum to the EC type-approval certificate granted in accordance with Commission Regulation (EU) No 582/2011.

▼M3

7.5 The actual value for assessment of conformity of the certified CO_2 emissions and fuel consumption related properties is the corrected specific fuel consumption over the WHSC, $SFC_{WHSC,corr}$, determined in accordance with points 7.2 and 7.3.

7.6 For dual-fuel engines point 7.5 shall not apply. Instead, the actual value for assessment of conformity of the certified CO_2 emissions and fuel consumption related properties is the sum of the two resulting values of specific CO_2 emissions over the WHSC determined in accordance with the provisions stated in point 6.1 of this Appendix using the two values of $SFC_{WHSC,corr}$ determined in accordance with point 7.4 of this Appendix.

▼M1

8. Limit for conformity of one single test

For diesel engines, the limit values for the assessment of conformity of one single engine tested shall be the target value determined in accordance with point (6) + 4 percent.

▼M3

For gas and dual-fuel engines, the limit values for the assessment of conformity of one single engine tested shall be the target value determined in accordance with point (6) + 5 %.

▼B

9. Assessment of conformity of the certified CO_2 emissions and fuel consumption related properties

▼M3

9.1 The emission test results over the WHSC determined in accordance with point 7.4 of this Appendix shall meet the following limit values for all gaseous pollutants except ammonia, otherwise the test shall be considered void for the assessment of conformity of the certified CO_2 emissions and fuel consumption related properties:

(a) applicable limit values defined in Annex I to Regulation (EC) No 595/2009

(b) dual-fuel engines shall meet the applicable limits defined in point 5 of Annex XVIII to Regulation (EU) No 582/2011

▼B

9.2 A single test of one engine tested in accordance with paragraph 4 of this Appendix shall be considered as nonconforming if the actual value in accordance with paragraph 7 of this Appendix is higher than the limit values defined in accordance with paragraph 8 of this Appendix.

9.3 For the current sample size of engines tested within one CO_2-family in accordance with paragraph 4 of this Appendix the test statistic quantifying the cumulative number of nonconforming tests in accordance with point 9.2 of this Appendix at the n^{th} test shall be determined.

(a) If the cumulative number of nonconforming tests at the n^{th} test determined in accordance with point 9.3 of this Appendix is less than or equal to the pass decision number for the sample size given in Table 4 of Appendix 3 to ►**M3** UN Regulation No. 49 ◄, a pass decision is reached.

(b) If the cumulative number of nonconforming tests at the n^{th} test determined in accordance with point 9.3 of this Appendix is greater than or equal to the fail decision number for the sample size given in Table 4 of Appendix 3 to ►**M3** UN Regulation No. 49 ◄, a fail decision is reached.

(c) Otherwise, an additional engine is tested in accordance with paragraph 4 of this Appendix and the calculation procedure in accordance with point 9.3 of this Appendix is applied to the sample increased by one more unit.

9.4 If neither a pass nor a fail decision is reached, the manufacturer may at any time decide to stop testing. In that case a fail decision is recorded.

▼B

Appendix 5

Determination of power consumption of engine components

1. Fan

The engine torque shall be measured at engine motoring with and without fan engaged with the following procedure:

(i) Install the fan according to product instruction before the test starts.

(ii) Warm up phase: The engine shall be warmed up according to the recommendation of the manufacturer and by practicing good engineering judgement (eg operating the engine for 20 minutes at mode 9, as defined in Table 1 of paragraph 7.2.2. of Annex 4 to ►M3 UN Regulation No. 49 ◄).

▼M1

(iii) Stabilization phase: After the warm-up or optional warm-up step (v) is completed the engine shall be operated with minimum operator demand (motoring) at engine speed n_{pref} for 130 ± 2 seconds with the fan disengaged ($n_{fan\_disengage} < 0{,}75 * n_{engine} * r_{fan}$). The first 60 ± 1 seconds of this period are considered as a stabilization period, during which the actual engine speed shall be held within ± 5 min^{-1} of n_{pref}.

▼B

(iv) Measurement phase: During the following period of 60 ± 1 seconds the actual engine speed shall be held within ± 2 min^{-1} of n_{pref} and the coolant temperature within ± 5 °C while the torque for motoring the engine with the fan disengaged, the fan speed and the engine speed shall be recorded as an average value over this period of 60 ± 1 seconds. The remaining period of 10 ± 1 seconds shall be used for data post-processing and storage if necessary.

(v) Optional warmup phase: Upon manufacturer's request and according to good engineering judgement step (ii) can be repeated (e.g. if the temperature has dropped more than 5 °C)

(vi) Stabilization phase: After the optional warm-up is completed the engine shall be operated with minimum operator demand (motoring) at engine speed n_{pref} for 130 ± 2 seconds with the fan engaged ($n_{fan\_engage} > 0{,}9 * n_{engine} * r_{fan}$) The first 60 ± 1 seconds of this period are considered as a stabilization period, during which the actual engine speed shall be held within ± 5 min^{-1} of $n_{pref.}$

(vii) Measurement phase: During the following period of 60 ± 1 seconds the actual engine speed shall be held within ± 2 min^{-1} of n_{pref} and the coolant temperature within ± 5 °C while the torque for motoring the engine with the fan engaged, the fan speed and the engine speed shall be recorded as an average value over this period of 60 ± 1 seconds. The remaining period of 10±1 seconds shall be used for data post-processing and storage if necessary.

(viii) Steps (iii) to (vii) shall be repeated at engine speeds n_{95h} and n_{hi} instead of n_{pref}, with an optional warmup step (v) before each stabilization step if needed to maintain a stable coolant temperature (± 5 °C), according to good engineering judgement.

▼B

(ix) If the standard deviation of all calculated C_i according to the equation below at the three speeds n_{pref}, n_{95h} and n_{hi} is equal or higher than 3 percent, the measurement shall be performed for all engine speeds defining the grid for the fuel mapping procedure (FCMC) according to paragraph 4.3.5.2.1.

The actual fan constant shall be calculated from the measurement data according to the following equation:

$$C_i = \frac{MD_{fan\_disengage} - MD_{fan\_engage}}{\left(n_{fan\_engage}{}^2 - n_{fan\_disengage}{}^2\right)} \cdot 10^6$$

where:

C_i	fan constant at certain engine speed
$MD_{fan\_disengage}$	measured engine torque at motoring with fan disengaged (Nm)
MD_{fan_engage}	measured engine torque at motoring with fan engaged (Nm)
n_{fan_engage}	fan speed with fan engaged (min^{-1})
$n_{fan\_disengage}$	fan speed with fan disengaged min^{-1})

▼M1

r_{fan}	ratio of the speed of the engine-side of the fan clutch to the speed of the crankshaft

▼B

If the standard deviation of all calculated C_i at the three speeds n_{pref}, n_{95h} and n_{hi} is less than 3 %, an average value $C_{avg\text{-}fan}$ determined over the three speeds n_{pref}, n_{95h} and n_{hi} shall be used for the fan constant.

If the standard deviation of all calculated C_i at the three speeds n_{pref}, n_{95h} and n_{hi} is equal or higher than 3 %, individual values determined for all engine speeds according to point (ix) shall be used for the fan constant $C_{ind\text{-}fan,i}$. The value of the fan constant for the actual engine speed $C_{fan,}$ shall be determined by linear interpolation between the individual values $C_{ind\text{-}fan,i}$ of the fan constant.

The engine torque for driving the fan shall be calculated according to the following equation:

$$M_{fan} = C_{fan} \cdot n_{fan}{}^2 \cdot 10^{-6}$$

where:

M_{fan} engine torque for driving fan (Nm)

C_{fan} fan constant $C_{avg\text{-}fan}$ or $C_{ind\text{-}fan,i}$ corresponding to n_{engine}

The mechanical power consumed by the fan shall be calculated from the engine torque for driving the fan and the actual engine speed. Mechanical power and engine torque shall be taken into account in accordance with paragraph 3.1.2.

2. Electric components/equipment

The electric power supplied externally to electric engine components shall be measured. This measured value shall be corrected to mechanical power by dividing it by a generic efficiency value of 0,65. This mechanical power and the corresponding engine torque shall be taken into account in accordance with paragraph 3.1.2.

▼B

Appendix 6

1. Markings

In the case of an engine being certified in accordance with this Annex, the engine shall bear:

▼M1

1.1. The manufacturer's name or trade mark

▼B

1.2 The make and identifying type indication as recorded in the information referred to in point 0.1 and 0.2 of Appendix 2 to this Annex

1.3 The certification mark as a rectangle surrounding the lower-case letter ‘e’ followed by the distinguishing number of the Member State which has granted the certificate:

1 for Germany;

2 for France;

3 for Italy;

4 for the Netherlands;

5 for Sweden;

6 for Belgium;

7 for Hungary;

8 for the Czech Republic;

9 for Spain;

11 for the United Kingdom;

12 for Austria;

13 for Luxembourg;

17 for Finland;

18 for Denmark;

19 for Romania;

20 for Poland;

21 for Portugal;

23 for Greece;

24 for Ireland;

25 for Croatia;

26 for Slovenia;

27 for Slovakia;

29 for Estonia;

32 for Latvia;

34 for Bulgaria;

36 for Lithuania;

49 for Cyprus;

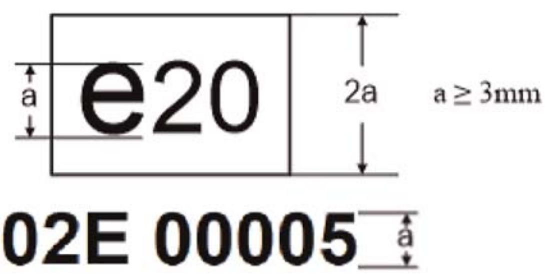
50 for Malta

▼M3

1.4 The certification mark shall also include in the vicinity of the rectangle the “base approval number” as specified for Section 4 of the type-approval number set out in Annex I to Implementing Regulation (EU) 2020/683, preceded by the two figures indicating the sequence number assigned to the latest technical amendment to this Regulation and by a character “E” indicating that the approval has been granted for an engine.

For this Regulation, the sequence number shall be 02.

1.4.1 Example and dimensions of the certification mark (separate marking)



▼M3

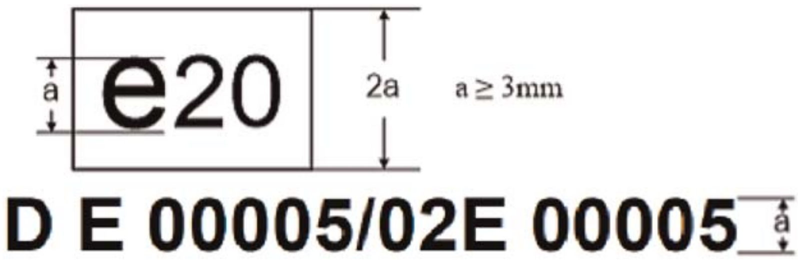
The above certification mark affixed to an engine shows that the type concerned has been certified in Poland (e20), pursuant to this Regulation. The first two digits (02) indicate the sequence number assigned to the latest technical amendment to this Regulation. The following letter indicates that the certificate was granted for an engine (E). The last five digits (00005) are those allocated by the approval authority to the engine as the base approval number.

▼M1

1.5. In the case that the certification in accordance with this Regulation is granted at the same time as the type approval for an engine as separate technical unit in accordance with Regulation (EU) No 582/2011, the marking requirements laid down in point 1.4 may follow, separated by '/', the marking requirements laid down in Appendix 8 to Annex I to Regulation (EU) No 582/2011.

▼M3

1.5.1. Example of the certification mark (joined marking)



The above certification mark affixed to an engine shows that the type concerned has been certified in Poland (e20), pursuant to Regulation (EU) No 582/2011. The 'D' indicates Diesel followed by an 'E' for the emission step followed by five digits (00005) which are those allocated by the approval authority to the engine as the base approval number for Regulation (EU) No 582/2011. After the slash the first two figures are indicating the sequence number assigned to the latest technical amendment to this Regulation, followed by a letter 'E' for engine, followed by five digits allocated by the approval authority for the purpose of certification in accordance with this Regulation ('base approval number' to this Regulation).

▼B

1.6. On request of the applicant for certification and after prior agreement with the approval authority other type sizes than indicated in point 1.4.1 and 1.5.1 may be used. Those other type sizes shall remain clearly legible.

1.7. The markings, labels, plates or stickers must be durable for the useful life of the engine and must be clearly legible and indelible. The manufacturer shall ensure that the markings, labels, plates or sticker cannot be removed without destroying or defacing them.

2 Numbering

▼M3

2.1 Certification number for engines shall comprise the following:

▼M3

eX*YYYY/YYYY*ZZZZ/ZZZZ*E*00000*00

section 1	section 2	section 3	Additional letter to section 3	section 4	section 5
Indication of country issuing the certification	HDV CO_2 determination Regulation '2017/2400'	Latest amending Regulation (ZZZZ/ZZZZ)	E - engine	Base certification number 00000	Extension 00

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Appendix 7

Input parameters for the simulation tool

Introduction

This Appendix describes the list of parameters to be provided by the component manufacturer as input to the simulation tool. The applicable XML schema as well as example data are available at the dedicated electronic distribution platform.

The XML is automatically generated by the engine pre-processing tool.

Definitions

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(1) ‘Parameter ID’: Unique identifier as used in the simulation tool for a specific input parameter or set of input data

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(2) ‘Type’: Data type of the parameter

string .... sequence of characters in ISO8859-1 encoding

token .... sequence of characters in ISO8859-1 encoding, no leading/trailing whitespace

date .... date and time in UTC time in the format: YYYY-MM-DD*T*HH:MM:SS*Z* with italic letters denoting *fixed characters* e.g. ‘2002-05-30*T*09:30:10*Z*’

integer .... value with an integral data type, no leading zeros, e.g. ‘1800’

double, X .... fractional number with exactly X digits after the decimal sign (‘.’) and no leading zeros e.g. for ‘double, 2’: ‘2345.67’; for ‘double, 4’: ‘45.6780’

(3) ‘Unit’ … physical unit of the parameter

Set of input parameters

▼M3

Table 1

Input parameters ‘Engine/General’

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P200	token	[-]	
Model	P201	token	[-]	
Certification-Number	P202	token	[-]	
Date	P203	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P204	token	[-]	Version number of engine pre-processing tool
Displacement	P061	int	[cm^3]	
IdlingSpeed	P063	int	[1/min]	

▼**M3**

Parameter name	Parameter ID	Type	Unit	Description/Reference
RatedSpeed	P249	int	[1/min]	
RatedPower	P250	int	[W]	
MaxEngineTorque	P259	int	[Nm]	
WHRTypeMechanicalOutputICE	P335	boolean	[-]	
WHRTypeMechanicalOutputDrivetrain	P336	boolean	[-]	
WHRTypeElectricalOutput	P337	boolean	[-]	
WHRElectricalCFUrban	P338	double, 4	[-]	Required if 'WHRTypeElectricalOutput' = true
WHRElectricalCFRural	P339	double, 4	[-]	Required if 'WHRTypeElectricalOutput' = true
WHRElectricalCFMotorway	P340	double, 4	[-]	Required if 'WHRTypeElectricalOutput' = true
WHRElectricalBFColdHot	P341	double, 4	[-]	Required if 'WHRTypeElectricalOutput' = true
WHRElectricalCFRegPer	P342	double, 4	[-]	Required if 'WHRTypeElectricalOutput' = true
WHRMechanicalCFUrban	P343	double, 4	[-]	Required if 'WHRTypeMechanicalOutputDrivetrain' = true
WHRMechanicalCFRural	P344	double, 4	[-]	Required if 'WHRTypeMechanicalOutputDrivetrain' = true
WHRMechanicalCFMotorway	P345	double, 4	[-]	Required if 'WHRTypeMechanicalOutputDrivetrain' = true
WHRMechanicalBFColdHot	P346	double, 4	[-]	Required if 'WHRTypeMechanicalOutputDrivetrain' = true
WHRMechanicalCFRegPer	P347	double, 4	[-]	Required if 'WHRTypeMechanicalOutputDrivetrain' = true

▼M3

Table 1a

Input parameters 'Engine' per fuel type

Parameter name	Parameter ID	Type	Unit	Description/Reference
WHTCUrban	P109	double, 4	[-]	
WHTCRural	P110	double, 4	[-]	
WHTCMotorway	P111	double, 4	[-]	
BFColdHot	P159	double, 4	[-]	
CFRegPer	P192	double, 4	[-]	
CFNCV	P260	double, 4	[-]	
FuelType	P193	string	[-]	Allowed values: 'Diesel CI', 'Ethanol CI', 'Petrol PI', 'Ethanol PI', 'LPG PI', 'NG PI', 'NG CI'

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Table 2

Input parameters 'Engine/FullloadCurve' for each grid point in the full load curve

Parameter name	Parameter ID	Type	Unit	Description/Reference
EngineSpeed	P068	double, 2	[1/min]	
MaxTorque	P069	double, 2	[Nm]	
DragTorque	P070	double, 2	[Nm]	

▼M3

Table 3

Input parameters 'Engine/FuelMap' for each grid point in the fuel map

(One map required per fuel type)

Parameter name	Parameter ID	Type	Unit	Description/Reference
EngineSpeed	P072	double, 2	[1/min]	
Torque	P073	double, 2	[Nm]	
FuelConsumption	P074	double, 2	[g/h]	
WHRElectric-Power	P348	int	[W]	Required if 'WHRTypeElectricalOutput' = true
WHRMechanical-Power	P349	int	[W]	Required if 'WHRTypeMechanicalOutputDrivetrain' = true

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Appendix 8

Important evaluation steps and equations of the engine pre-processing tool

This Appendix describes the most important evaluation steps and underlying basic equations that are performed by the engine pre-processing tool. The following steps are performed during evaluation of the input data in the order listed:

1. Reading of input files and automatic check of input data

1.1 Check of requirements for input data according to the definitions in paragraph 6.1 of this Annex

1.2 Check of requirements for recorded FCMC data according to the definitions in paragraph 4.3.5.2 and subpoint (1) of paragraph 4.3.5.5 of this Annex

2. Calculation of characteristic engine speeds from full load curves of parent engine and actual engine for certification according to the definitions in paragraph 4.3.5.2.1 of this Annex

3. Processing of fuel consumption (FC) map

3.1 FC values at n_{idle} are copied to engine speed (n_{idle} – 100 min^{-1}) in the map

3.2 FC values at n_{95h} are copied to engine speed (n_{95h} + 500 min^{-1}) in the map

3.3 Extrapolation of FC values at all engine speed setpoints to a torque value of (1.1 times $T_{max\_overall}$) by using least squares linear regression based on the 3 measured FC points with the highest torque values at each engine speed setpoint in the map. ►M3 Extrapolated FC values lower than the measured value at full load at the respective engine speed are set to the measured value at full load. ◄

3.4 Adding of FC = 0 for interpolated motoring torque values at all engine speed setpoints in the map

3.5 Adding of FC = 0 for minimum of interpolated motoring torque values from subpoint (3.4) minus 100 Nm at all engine speed setpoints in the map

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3.6 Adding of WHR power = 0 at all points referred to in points (3.4) and (3.5).

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4. Simulation of FC and cycle work over WHTC and respective subparts for actual engine for certification

4.1. WHTC reference points are denormalized using the full load curve input in originally recorded resolution

4.2. FC is calculated for WHTC denormalized reference values for engine speed and torque from subpoint 4.1

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4.3. FC is calculated with engine inertia set to 0

4.4. FC is calculated with standard PT1-function (as in main vehicle simulation) for engine torque response active

4.5. FC for all motoring points is set to 0

4.6. FC for all non-motoring engine operation points is calculated from FC map by Delaunay interpolation method (as in main vehicle simulation)

4.7. Cycle work and FC are calculated according to equations defined in paragraphs 5.1 and 5.2 of this Annex

4.8. Simulated specific FC values are calculated analogous to equations defined in paragraphs 5.3.1 and 5.3.2 of this Annex for measured values

5. Calculation of WHTC correction factors

5.1. Measured values from input to pre-processing tool and simulated values from point (4) are used in accordance with the equations in points (5.2) to (5.4)

5.2. $CF_{Urban} = SFCmeas,_{Urban}/SFCsimu,_{Urban}$

5.3. $CF_{Rural} = SFCmeas,_{Rural}/SFCsimu,_{Rural}$

5.4. $CF_{MW} = SFCmeas,_{MW}/SFCsimu,_{MW}$

5.5. In case that the calculated value for a correction factor is lower than 1, the respective correction factor is set to 1

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5.6. In the case of dual-fuel engines, the calculated value for a correction factor for a specific fuel type may be lower than 1.

5.7. Notwithstanding point (5.6), if in the case of dual-fuel engines, the ratio of the measured total specific fuel energy values over the simulated total specific fuel energy values of both fuels is lower than 1, the specific fuel consumption values are adapted accordingly by the engine pre-processing tool so that the aforementioned ratio results in a value of 1.

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6. Calculation of cold-hot emission balancing factor

6.1. This factor is calculated in accordance with the equation in point (6.2)

6.2. $BF_{cold\text{-}hot} = 1 + 0{,}1 \times (SFC_{meas,cold} - SFC_{meas,hot})/SFC_{meas,hot}$

6.3. In case that the calculated value for this factor is lower than 1, the factor is set to 1

7. Correction of FC values in FC map to standard NCV

7.1. This correction is performed in accordance with the equation in point (7.2)

7.2. $FC_{corrected} = FC_{measured,map} \times NCV_{meas}/NVC_{std}$

7.3. $FC_{measured,map}$ shall be the FC value in the FC map input data processed in accordance with point (3)

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7.4. NCV_{meas} and NVC_{std} shall be defined in accordance with paragraph 5.3.3.1 of this Annex

7.5. In the case that reference fuel of the type B7 (Diesel / CI) in accordance with paragraph 3.2 of this Annex was used during testing, the correction in accordance with points (7.1) to (7.4) is not performed.

8. Converting of engine full load and motoring torque values of the actual engine for certification to a logging frequency of the engine speed of 8 min^{-1}

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8.1. If the average logging frequency of the engine speed of the originally recorded full load curve is smaller than 6, the conversion is performed by arithmetical averaging over intervals of ± 4 min^{-1} of the given setpoint for the output data based on the full load curve input in originally recorded resolution. If the average logging frequency of the engine speed of the originally recorded full load curve is greater than or equal to 6, the conversion is performed by linear interpolation based on the full load curve input in originally recorded resolution.

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ANNEX VI

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

1. Introduction

This annex describes the certification provisions regarding the torque losses of transmissions, torque converter (TC), other torque transferring components (OTTC) and additional driveline components (ADC) for heavy duty vehicles. In addition it defines calculation procedures for the standard torque losses.

Torque converter (TC), other torque transferring components (OTTC) and additional driveline components (ADC) can be tested in combination with a transmission or as a separate unit. In the case that those components are tested separately the provisions of section 4, 5 and 6 apply. Torque losses resulting from the drive mechanism between the transmission and those components can be neglected.

2. Definitions

For the purposes of this Annex the following definitions shall apply:

(1) 'Transfer case' means a device that splits the engine power of a vehicle and directs it to the front and rear drive axles. It is mounted behind the transmission and both front and rear drive shafts connect to it. It comprises either a gearwheel set or a chain drive system in which the power is distributed from the transmission to the axles. The transfer case will typically have the ability to shift between standard drive mode (front or rear wheel drive), high range traction mode (front and rear wheel drive), low range traction mode and neutral;

(2) 'Gear ratio' means the forward gear ratio of the speed of the input shaft (towards prime mover) to the speed of the output shaft (towards driven wheels) without slip ($i = n_{in}/n_{out}$);

(3) 'Ratio coverage' means the ratio of the largest to the smallest forward gear ratios in a transmission: $\varphi_{tot} = i_{max}/i_{min}$;

(4) 'Compound transmission' means a transmission, with a large number of forward gears and/or large ratio coverage, composed of sub-transmissions, which are combined to use most power-transferring parts in several forward gears;

(5) 'Main section' means the sub-transmission that has the largest number of forward gears in a compound transmission;

(6) 'Range section' means a sub-transmission normally in series connection with the main section in a compound transmission. A range section usually has two shiftable forward gears. The lower forward gears of the complete transmission are embodied using the low range gear. The higher gears are embodied using the high range gear;

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(7) 'Splitter' means a design that splits the main section gears in two (usually) variants, low- and high split gears, whose gear ratios are close compared to the ratio coverage of the transmission. A splitter can be a separate sub-transmission, an add-on device, integrated with the main section or a combination thereof;

(8) 'Tooth clutch' means a clutch where torque is transferred mainly by normal forces between mating teeth. A tooth clutch can either be engaged or disengaged. It is operated in load-free conditions, only (e.g., at gear shifts in a manual transmission);

(9) 'Angle drive' means a device that transmits rotational power between non-parallel shafts, often used with transversely oriented engine and longitudinal input to driven axle;

(10) 'Friction clutch' means clutch for transfer of propulsive torque, where torque is sustainably transferred by friction forces. A friction clutch can transmit torque while slipping, it can thereby (but does not have to) be operated at start-offs and at powershifts (retained power transfer during a gear shift);

(11) 'Synchroniser' means a type of tooth clutch where a friction device is used to equalise the speeds of the rotating parts to be engaged;

(12) 'Gear mesh efficiency' means the ratio of output power to input power when transmitted in a forward gear mesh with relative motion;

(13) 'Crawler gear' means a low forward gear (with speed reduction ratio that is larger than for the non-crawler gears) that is designed to be used infrequently, e.g., at low-speed manoeuvres or occasional up-hill start-offs;

(14) 'Power take-off (PTO)' means a device on a transmission or an engine to which an auxiliary driven device, e.g., a hydraulic pump, can be connected;

(15) 'Power take-off drive mechanism' means a device in a transmission that allows the installation of a power take-off (PTO);

(16) 'Lock-up clutch' means a friction clutch in a hydrodynamic torque converter; it can connect the input and output sides, thereby eliminating the slip. ►M3 In some cases permanent slip in fixed gears is intended, e.g. to prevent vibrations; ◄

(17) ►M3 'Start-off clutch' means a clutch that adapts speed between engine and driving wheels when the vehicle starts off. ◄ The start-off clutch is usually located between engine and transmission;

(18) 'Synchronised Manual Transmission (SMT)' means a manually operated transmission with two or more selectable speed ratios that are obtained using synchronisers. Ratio changing is normally achieved during a temporary disconnection of the transmission from the engine using a clutch (usually the vehicle start-off clutch);

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(19) 'Automated Manual Transmission or Automatic Mechanically-engaged Transmission (AMT)' means an automatically shifting transmission with two or more selectable speed ratios that are obtained using tooth clutches (un-/synchronised). Ratio changing is achieved during a temporary disconnection of the transmission from the engine. The ratio shifts are performed by an electronically controlled system managing the timing of the shift, the operation of the clutch between engine and gearbox and the speed and torque of the engine. The system selects and engages the most suitable forward gear automatically, but can be overridden by the driver using a manual mode;

(20) 'Dual Clutch Transmission (DCT)' means an automatically shifting transmission with two friction clutches and several selectable speed ratios that are obtained by the use of tooth clutches. The ratio shifts are performed by an electronically controlled system managing the timing of the shift, the operation of the clutches and the speed and torque of the engine. The system selects the most suitable gear automatically, but can be overridden by the driver using a manual mode. ►M3 In some cases permanent slip in fixed gears is intended, e.g. to prevent vibrations; ◄

(21) 'Retarder' means an auxiliary braking device in a vehicle powertrain; aimed for permanent braking;

▼M3

(22) 'Case S' means an Automatic Powershifting Transmission (APT) with serial arrangement of a torque converter and the connected mechanical parts of the transmission;

(23) 'Case P' means an APT with parallel arrangement of a torque converter and the connected mechanical parts of the transmission (e.g. in power split installations);

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(24) 'Automatic Powershifting Transmission (APT)' means an automatically shifting transmission with more than two friction clutches and several selectable speed ratios that are obtained mainly by the use of those friction clutches. The ratio shifts are performed by an electronically controlled system managing the timing of the shift, the operation of the clutches and the speed and torque of the engine. The system selects the most suitable gear automatically, but can be overridden by the driver using a manual mode. Shifts are normally performed without traction interruption (friction clutch to friction clutch);

(25) 'Oil conditioning system' means an external system that conditions the oil of a transmission at testing. The system circulates oil to and from the transmission. The oil is thereby filtered and/or temperature conditioned;

(26) 'Smart lubrication system' means a system that will affect the load independent losses (also called spin losses or drag losses) of the transmission depending on the input torque and/or power flow through the transmission. Examples are controlled hydraulic pressure pumps for brakes and clutches in an APT, controlled variable oil level in the transmission, controlled variable oil flow/pressure for lubrication and cooling in the transmission. Smart lubrication can also include control of

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the oil temperature of the transmission, but smart lubrication systems that are designed only for controlling the temperature are not considered here, since the transmission testing procedure has fixed testing temperatures;

(27) 'Transmission electric auxiliary' means an electric auxiliary used for the function of the transmission during running steady state operation. A typical example is an electric cooling/lubrication pump (but not electric gear shift actuators and electronic control systems including electric solenoid valves, since they are low energy consumers, especially at steady state operation);

(28) 'Oil type viscosity grade' means a viscosity grade as defined by SAE J306;

(29) 'Factory fill oil' means the oil type viscosity grade that is used for the oil fill in the factory and which is intended to stay in the transmission, torque converter, other torque transferring component or in an additional driveline component for the first service interval;

(30) 'Gearscheme' means the arrangement of shafts, gearwheels and clutches in a transmission;

(31) 'Powerflow' means the transfer path of power from input to output in a transmission via shafts, gearwheels and clutches;

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(32) 'Differential' means a device that splits a torque into two branches, e.g. for left- and right-hand side wheels, while allowing these branches to rotate at unequal speeds. The torque-splitting function can be biased or deactivated by a differential brake- or differential lock device (if applicable);

(33) 'Case N' means an APT without a torque converter.

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3. Testing procedure for transmissions

For testing the losses of a transmission the torque loss map for each individual transmission type shall be measured. Transmissions may be grouped into families with similar or equal CO_2-relevant data following the provisions of Appendix 6 to this Annex.

For the determination of the transmission torque losses, the applicant for a certificate shall apply one of the following methods for each single forward gear (crawler gears excluded).

(1) Option 1: Measurement of the torque independent losses, calculation of the torque dependent losses.

(2) Option 2: Measurement of the torque independent losses, measurement of the torque loss at maximum torque and interpolation of the torque dependent losses based on a linear model

(3) Option 3: Measurement of the total torque loss.

3.1 Option 1: Measurement of the torque independent losses, calculation of the torque dependent losses.

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The torque loss $T_{l,in}$ on the input shaft of the transmission shall be calculated by

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$$T_{l,in}(n_{in},T_{in},gear) = T_{l,in,min\_loss} + f_T \times T_{in} + f_{loss\_corr} \times T_{in} + T_{l,in,min\_el} + f_{el\_corr} \times T_{in} + f_{loss_{tcc}} \times T_{in}$$

▼B

The correction factor for the torque dependent hydraulic torque losses shall be calculated by

$$f_{loss\_corr} = \frac{(T_{l,in,max\_loss} - T_{l,in,min\_loss})}{T_{max,in}}$$

The correction factor for the torque dependent electric torque losses shall be calculated by

$$f_{el\_corr} = \frac{(T_{l,in,max\_el} - T_{l,in,min\_el})}{T_{max,in}}$$

The torque loss at the input shaft of the transmission caused by the power consumption of transmission electric auxiliary shall be calculated by

$$T_{l,in,el} = \frac{P_{el}}{\left(0{,}7 \times n_{in} \times \frac{2\pi}{60}\right)}$$

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The correction factor for the losses in a slipping TC lock-up clutch as defined in point 2(16) or slipping input side clutch as defined in point 2(20) shall be calculated by:

$$f_{loss_{tcc}} = \frac{\Delta n_{tcc}}{n_{in}}$$

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where:

$T_{l,in}$ = Torque loss related to input shaft [Nm]

T_{l,in,min_loss} = Torque independent loss at minimum hydraulic loss level (minimum main pressure, cooling/lubrication flows etc.), measured with free rotating output shaft from testing without load [Nm]

T_{l,in,max_loss} = Torque independent loss at maximum hydraulic loss level (maximum main pressure, cooling/lubrication flows etc.), measured with free rotating output shaft from testing without load [Nm]

f_{loss_corr} = Loss correction for hydraulic loss level depending on input torque [-]

n_{in} = Speed at the transmission input shaft (downstream of torque converter, if applicable) [rpm]

f_T = Torque loss coefficient = $1 - \eta_T$

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T_{in} = Torque at the input shaft [Nm]

η_T = Torque dependent efficiency (to be calculated); for a direct gear f_T = 0,007 (η_T = 0,993) [-]

f_{el_corr} = Loss correction for electric power loss level depending on input torque [-]

$T_{l,in,\ el}$ = Additional torque loss on input shaft by electric consumers [Nm]

T_{l,in,min_el} = Additional torque loss on input shaft by electric consumers corresponding to minimum electric power [Nm]

T_{l,in,max_el} = Additional torque loss on input shaft by electric consumers corresponding to maximum electric power [Nm]

P_{el} = Electric power consumption of electric consumers in transmission measured during transmission loss testing [W]

$T_{max,in}$ = Maximum allowed input torque for any forward gear in the transmission [Nm]

▼M3

f_{loss_tcc} = Loss correction factor for slipping torque converter (or input side) clutch

n_{tcc} = Difference in speed between upstream and downstream side of slipping TC lock-up clutch as defined in point 2(16) or slipping input side clutch as defined in 2(20) [rpm] (speed downstream of the slipping clutch is the speed n_{in} at the transmission input shaft)

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3.1.1. The torque dependent losses of a transmission system shall be determined as described in the following:

In case of multiple parallel and nominally equal power flows, e.g., twin countershafts or several planet gearwheels in a planetary gear set, that can be treated as one power flow in this section.

3.1.1.1. For each indirect gear g of common transmissions with a non-split power flow and ordinary, non-planetary gear sets, the following steps shall be performed:

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3.1.1.2. For each active gear mesh, the torque dependent efficiency shall be set to constant values of ηm:

external – external gear meshes : $\eta_m = 0{,}986$

external – internal gear meshes : $\eta_m = 0{,}993$

angle drive gear meshes : $\eta_m = 0{,}97$

(Angle drive losses may alternatively be determined by separate testing as described in paragraph 6. of this Annex)

3.1.1.3. The product of these torque dependent efficiencies in active gear meshes shall be multiplied with a torque dependent bearing efficiency ηb = 99,5 %.

3.1.1.4. The total torque dependent efficiency η_{Tg} for the gear g shall be calculated by:

$$\eta_{Tg} = \eta_b * \eta_{m,1} * \eta_{m,2} * [\ldots] * \eta_{m,n}$$

3.1.1.5. The torque dependent loss coefficient f_{Tg} for the gear g shall be calculated by:

$$f_{Tg} = 1 - \eta_{Tg}$$

3.1.1.6. The torque dependent loss $T_{l,inTg}$ on the input shaft for gear g shall be calculated by:

$$T_{l,inTg} = f_{Tg} * T_{in}$$

3.1.1.7. The torque dependent efficiency of the planetary range section in low range state for the special case of transmissions consisting of a countershaft-type main section in series with a planetary range section (with non-rotating ring gearwheel and the planet carrier connected to the output shaft) may, alternatively to the procedure described in 3.1.1.8., be calculated by:

$$\eta_{lowrange} = \frac{1 + \eta_{m,ring} \times \eta_{m,sun} \times \frac{z_{ring}}{z_{sun}}}{1 + \frac{z_{ring}}{z_{sun}}}$$

where:

$\eta_{m,ring}$ = Torque dependent efficiency of the ring-to-planet gear mesh = 99,3 % [-]

$\eta_{m,sun}$ = Torque dependent efficiency of the planet-to-sun gear mesh = 98,6 % [-]

z_{sun} = Number of teeth of the sun gearwheel of the range section [-]

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z_{ring} = Number of teeth of the ring gearwheel of the range section [-]

The planetary range section shall be regarded as an additional gear mesh within the countershaft main section, and its torque dependent efficiency $\eta_{lowrange}$ shall be included in the determination of the total torque dependent efficiencies η_{Tg} for the low-range gears in the calculation in 3.1.1.4.

3.1.1.8. For all other transmission types with more complex split power flows and/or planetary gear sets (e.g. a conventional automatic planetary transmission), the following simplified method shall be used to determine the torque dependent efficiency. The method covers transmission systems composed of ordinary, non-planetary gear sets and/or planetary gear sets of ring-planet-sun type. Alternatively the torque dependent efficiency may be calculated based on VDI Regulation No. 2157. Both calculations shall use the same constant gear mesh efficiency values defined in 3.1.1.2.

In this case, for each indirect gear *g*, the following steps shall be performed:

3.1.1.9. Assuming 1 rad/s of input speed and 1 Nm of input torque, a table of speed (N_i) and torque (T_i) values for all gearwheels with a fix rotational axis (sun gearwheels, ring gearwheels and ordinary gearwheels) and planet carriers shall be created. Speed and torque values shall follow the right-hand rule, with engine rotation as the positive direction.

3.1.1.10. For each planetary gear set, the relative speeds sun-to-carrier and ring-to-carrier shall be calculated by:

$$N_{sun-carrier} = N_{sun} - N_{carrier}$$

$$N_{ring-carrier} = N_{ring} - N_{carrier}$$

where:

N_{sun} = Rotational speed of sun gearwheel [rad/s]

N_{ring} = Rotational speed of ring gearwheel [rad/s]

$N_{carrier}$ = Rotational speed of carrier [rad/s]

3.1.1.11. The loss-producing powers in the gear meshes shall be computed in the following way:

For each ordinary, non-planetary gear set, the power *P* shall be calculated by:

$$P_1 = N_1 \cdot T_1$$

$$P_2 = N_2 \cdot T_2$$

where:

P = Power of gear mesh [W]

N = Rotational speed of gearwheel [rad/s]

T = Torque of gearwheel [Nm]

▼B

For each planetary gear set, the virtual power of sun $P_{v,sun}$ and ring gearwheels $P_{v,ring}$ shall be calculated by:

$$P_{v,sun} = T_{sun} \cdot (N_{sun} - N_{carrier}) = T_{sun} \cdot N_{sun/carrier}$$

$$P_{v,ring} = T_{ring} \cdot (N_{ring} - N_{carrier}) = T_{ring} \cdot N_{ring/carrier}$$

where:

$P_{v,sun}$ = Virtual power of sun gearwheel [W]

$P_{v,ring}$ = Virtual power of ring gearwheel [W]

T_{sun} = Torque of sun gearwheel [Nm]

$T_{carrier}$ = Torque of carrier [Nm]

T_{ring} = Torque of ring gearwheel [Nm]

Negative virtual power results shall indicate power leaving the gear set, positive virtual power results shall indicate power going into the gear set.

The loss-adjusted powers P_{adj} of the gear meshes shall be computed in the following way:

For each ordinary, non-planetary gear set, the negative power shall be multiplied by the appropriate torque dependent efficiency η_m:

$$P_i > 0 \Rightarrow P_{i,adj} = P_i$$

$$P_i < 0 \Rightarrow P_{i,adj} = P_i \cdot \eta_{mi}$$

where:

P_{adj} = Loss-adjusted powers of the gear meshes [W]

η_m = Torque dependent efficiency (appropriate to gear mesh; see 3.1.1.2.) [-]

For each planetary gear set, the negative virtual power shall be multiplied by the torque-dependent efficiencies of sun-to-planet η_{msun} and ring-to-planet η_{mring}:

$$P_{v,i} \geq 0 \Rightarrow P_{i,adj} = P_{v,i}$$

$$P_{v,i} < 0 \Rightarrow P_{i,adj} = P_i \cdot \eta_{msun} \cdot \eta_{mring}$$

where:

η_{msun} = Torque dependent efficiency of sun-to-planet [-]

η_{mring} = Torque dependent efficiency of ring-to-planet [-]

▼B

3.1.1.12. All loss-adjusted power values shall be added up to the torque dependent gear mesh power loss $P_{m,loss}$ of the transmission system referring to the input power:

$$P_{m,loss} = \Sigma P_{i,adj}$$

where:

i = All gearwheels with a fix rotational axis [-]

$P_{m,loss}$ = Torque dependent gear mesh power loss of the transmission system [W]

3.1.1.13. The torque dependent loss coefficient for bearings,

$$f_{T,bear} = 1 - \eta_{bear} = 1 - 0,995 = 0,005$$

and the torque dependent loss coefficient for the gear mesh

$$f_{T,gearmesh} = \frac{P_{m,loss}}{P_{in}} = \frac{P_{m,loss}}{\left(1\ Nm \times 1\,\frac{rad}{s}\right)}$$

shall be added to receive the total torque dependent loss coefficient f_T for the transmission system:

$$f_T = f_{T,gearmesh} + f_{T,bear}$$

where:

f_T = Total torque dependent loss coefficient for the transmission system [-]

$f_{T,bear}$ = Torque dependent loss coefficient for the bearings [-]

$f_{T,gearmesh}$ = Torque dependent loss coefficient for the gear meshes [-]

P_{in} = Fixed input power of the transmission; P_{in} = (1 Nm * 1 rad/s) [W]

3.1.1.14. The torque dependent losses on the input shaft for the specific gear shall be calculated by:

$$T_{l,inT} = f_T * T_{in}$$

where:

$T_{l,inT}$ = Torque dependent loss related to input shaft [Nm]

T_{in} = Torque at the input shaft [Nm]

3.1.2. The torque independent losses shall be measured in accordance with the procedure described in the following.

3.1.2.1. General requirements

The transmission used for the measurements shall be in accordance with the drawing specifications for series production transmissions and shall be new.

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Modifications to the transmission to meet the testing requirements of this Annex, e.g. for the inclusion of measurement sensors or adaption of an external oil conditioning system are permitted.

The tolerance limits in this paragraph refer to measurement values without sensor uncertainty.

▼M1

Total tested time per transmission individual and gear shall not exceed 5 times the actual testing time per gear (allowing re-testing of transmission if needed due to measuring or rig error).

▼B

The same transmission individual may be used for a maximum of 10 different tests, e.g. for tests of transmission torque losses for variants with and without retarder (with different temperature requirements) or with different oils. If the same transmission individual is used for tests of different oils, the recommended factory fill oil shall be tested first.

It is not permitted to run a certain test multiple times to choose a test series with the lowest results.

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

3.1.2.2. Differential measurements

To subtract influences caused by the test rig setup (e.g. bearings, clutches) from the measured torque losses, differential measurements are permitted to determine these parasitic torques. ►M3 The measurements shall be performed at the same speed points and same test rig bearing temperature(s) ± 3 K used for the testing. ◄ The torque sensor measurement uncertainty shall be below 0,3 Nm.

3.1.2.3. Run-in

On request of the applicant a run-in procedure may be applied to the transmission. The following provisions shall apply for a run-in procedure.

3.1.2.3.1. The procedure shall not exceed 30 hours per gear and 100 hours in total.

3.1.2.3.2. The application of the input torque shall be limited to 100 % of maximum input torque.

3.1.2.3.3. The maximum input speed shall be limited by the specified maximum speed for the transmission.

3.1.2.3.4. The speed and torque profile for the run-in procedure shall be specified by the manufacturer.

3.1.2.3.5. The run-in procedure shall be documented by the manufacturer with regard to run-time, speed, torque and oil temperature and reported to the Approval authority.

3.1.2.3.6. The requirements for the ambient temperature (3.1.2.5.1.), measurement accuracy (3.1.4.), test set-up (3.1.8.) and installation angle (3.1.3.2) shall not apply for the run-in procedure.

▼B

3.1.2.4. Pre-conditioning

3.1.2.4.1. Pre-conditioning of the transmission and the test rig equipment to achieve correct and stable temperatures before the run-in and testing procedures is allowed.

▼M3

3.1.2.4.2. The pre-conditioning shall be performed without applied torque to the non driven shaft.

▼B

3.1.2.4.3. The maximum input speed shall be limited by the specified maximum speed for the transmission.

3.1.2.4.4. The maximum combined time for the pre-conditioning shall not exceed 50 hours in total for one transmission. Since the complete testing of a transmission may be divided into multiple test sequences (e.g. each gear tested with a separate sequence), the pre-conditioning may be split into several sequences. Each of the single pre-conditioning sequences shall not exceed ►M3 100 ◄ minutes.

3.1.2.4.5. The pre-conditioning time shall not be accounted to the time span allocated for the run-in or test procedures.

3.1.2.5. Test conditions

3.1.2.5.1. Ambient temperature

The ambient temperature during the test shall be in a range of 25 °C ± 10 K.

The ambient temperature shall be measured 1 m laterally from the transmission.

The ambient temperature limit shall not apply for the run-in procedure.

3.1.2.5.2. Oil temperature

Except for the oil, no external heating is allowed.

During measurement (except stabilization) the following temperature limits shall apply:

For SMT/AMT/DCT transmissions, the drain plug oil temperature shall not exceed 83 °C when measuring without retarder and 87 °C with retarder mounted to the transmission. If measurements of a transmission without retarder are to be combined with separate measurements of a retarder, the lower temperature limit shall apply to compensate for the retarder drive mechanism and step-up gear and for the clutch in case of a disengageable retarder.

For torque converter planetary transmissions and for transmissions having more than two friction clutches, the drain plug oil temperature shall not exceed 93 °C without retarder and 97 °C with retarder.

To apply the above defined increased temperature limits for testing with retarder, the retarder shall be integrated in the transmission or have an integrated cooling or oil system with the transmission.

▼B

During the run-in, the same oil temperature specifications as for regular testing shall apply.

Exceptional oil temperature peaks up to 110 °C are allowed for the following conditions:

(1) during run-in procedure up to maximum of 10 % of the applied run-in time,

(2) during stabilization time.

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

3.1.2.5.3. Oil quality

New, recommended first fill oil for the European market shall be used in the test. The same oil fill may be used for run-in and torque measurement.

3.1.2.5.4. Oil viscosity

If multiple oils are recommended for first fill, they are considered to be equal if the oils have a kinematic viscosity within 10 % of each other at the same temperature (within the specified tolerance band for KV100). Any oil with lower viscosity than the oil used in the test shall be considered to result in lower losses for the tests performed within this option. Any additional first fill oil must fall either in the 10 % tolerance band or have lower viscosity than the oil in the test to be covered by the same certificate.

3.1.2.5.5. Oil level and conditioning

The oil level shall meet the nominal specifications for the transmission.

If an external oil conditioning system is used, the oil inside the transmission shall be kept to the specified volume that corresponds to the specified oil level.

To guarantee that the external oil conditioning system is not influencing the test, one test point shall be measured with the conditioning system both on and off. The deviation between the two measurements of the torque loss (= input torque) shall be less than 5 %. The test point is specified as follows:

(1) gear = highest indirect gear,

▼M3

(2) input speed = minimum of 60 % of the maximum input speed, not higher than 80 % of the maximum input speed,

▼B

(3) temperatures as specified under 3.1.2.5.

For transmissions with hydraulic pressure control or a smart lubrication system, the measurement of torque independent losses shall be performed with two different settings: first with the transmission system pressure set to at least the minimum value for conditions with engaged gear and a second time with the maximum possible hydraulic pressure (see 3.1.6.3.1).

3.1.3. Installation

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3.1.3.1. The electric machine and the torque sensor shall be mounted to the input side of the transmission. The output shaft(s) shall rotate freely. In the case of a transmission with an integrated differential, e.g. for

▼M3

front-wheel drive operation, the output ends shall be allowed to be rotatably locked into each other (e.g. by an activated differential lock or by means of any other mechanical differential lock implemented only for the measurement).

▼B

3.1.3.2. The installation of the transmission shall be done with an angle of inclination as for installation in the vehicle according to the homologation drawing ± 1° or at 0° ± 1°.

3.1.3.3. The internal oil pump shall be included in the transmission.

3.1.3.4. If an oil cooler is either optional or required with the transmission, the oil cooler may be excluded in the test or any oil cooler may be used in the test.

3.1.3.5. Transmission testing can be done with or without power take-off drive mechanism and/or power take-off. For establishing the power losses of power take-offs and /or power take-off drive mechanism, the values in ►M3 Annex IX ◄ to this regulation are applied. These values assume that the transmission is tested without power take-off drive mechanism and /or power take-off.

3.1.3.6. Measuring the transmission may be performed with or without single dry clutch (with one or two plates) installed. Clutches of any other type shall be installed during the test.

3.1.3.7. The individual influence of parasitic loads shall be calculated for each specific test rig setup and torque sensor as described in 3.1.8.

3.1.4. Measurement equipment

The calibration laboratory facilities shall comply with the requirements of either ►M3 IATF ◄ 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.

3.1.4.1. Torque

The torque sensor measurement uncertainty shall be below 0,3 Nm.

The use of torque sensors with higher measurement uncertainties is allowed if the part of the uncertainty exceeding 0,3 Nm can be calculated and is added to the measured torque loss as described in 3.1.8. Measurement uncertainty.

3.1.4.2. Speed

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

3.1.4.3. Temperature

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

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

3.1.4.4. Pressure

The uncertainty of the pressure sensors shall not exceed 1 % of the maximum measured pressure.

▼B

3.1.4.5. Voltage

The uncertainty of the voltmeter shall not exceed 1 % of the maximum measured voltage.

3.1.4.6. Electric current

The uncertainty of the amperemeter shall not exceed 1 % of the maximum measured current.

3.1.5. Measurement signals and data recording

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

(1) Input torques [Nm]

(2) Input rotational speeds [rpm]

(3) Ambient temperature [°C]

(4) Oil temperature [°C]

If the transmission is equipped with a shift and/or clutch system that is controlled by hydraulic pressure or with a mechanically driven smart lubrication system, additionally to be recorded:

(5) Oil pressure [kPa]

If the transmission is equipped with transmission electric auxiliary, additionally to be recorded:

(6) Voltage of transmission electric auxiliary [V]

(7) Current of transmission electric auxiliary [A]

For differential measurements for the compensation of influences caused by the test rig setup, additionally shall be recorded:

(8) Test rig bearing temperature [°C]

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

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

3.1.6. Test procedure

3.1.6.1. Zero torque signal compensation:

The zero-signal of the torque sensor(s) shall be measured. For the measurement the sensor(s) shall be installed in the test rig. The drivetrain of the test rig (input & output) shall be free of load. The measured signal deviation from zero shall be compensated.

▼M3

3.1.6.2. The torque loss shall be measured for the following speed points (speed of the input shaft): 600, 900, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000 rpm and multiples of 10 of these values up to the maximum speed per gear in accordance with the specifications of the transmission or the last speed point before the defined maximum speed. It is permitted to measure additional intermediate speed points.

The speed ramp (time for the change between two speed points) shall not exceed 20 seconds.

▼B

3.1.6.3. Measurement sequence:

3.1.6.3.1. If the transmission is equipped with smart lubrication systems and/or transmission electric auxiliaries, the measurement shall be conducted with two measurement settings of of these systems:

▼B

A first measurement sequence (3.1.6.3.2. to 3.1.6.3.4.) shall be performed with the lowest power consumption by hydraulical and electrical systems when operated in the vehicle (low loss level).

The second measurement sequence shall be performed with the systems set to work with the highest possible power consumption when operated in the vehicle (high loss level).

3.1.6.3.2. The measurements shall be performed beginning with the lowest up to the highest speed.

3.1.6.3.3. ►M3 For each speed point a minimum of 5-second stabilisation time within the temperature limits defined in 3.1.2.5 is required. ◄ If needed, the stabilization time may be extended by the manufacturer to maximum 60 seconds. Oil and ambient temperatures shall be recorded during the stabilization.

▼M3

3.1.6.3.4. After the stabilisation time, the torque loss should be constant at the actual measured speed point over time. If so, the measurement signals listed in 3.1.5. shall be recorded for a minimum of 5 seconds but for no longer than 15 seconds. If the torque loss is not constant at the actual measured speed point over time, e.g. by intended periodic variation of the torque losses caused by active or passive means of control, the manufacturer shall use the testing time required to get a reproducible and representative result.

▼B

3.1.6.3.5. Each measurement shall be performed two times per measurement setting.

3.1.7. Measurement validation

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3.1.7.1. The arithmetic mean values shall be calculated for each of the measurements of torque, speed, (if applicable) voltage and current. The measurements to be performed for a minimum of 5 seconds but for no longer than 15 seconds. If the torque loss is not constant at the actual measured speed point over time, e.g. by intended periodic variation of the torque losses caused by active or passive means of control, the manufacturer shall use the testing time required to get a reproducible and representative result.

▼B

3.1.7.2. The averaged speed deviation shall be below ± 5 rpm of the speed set point for each measured point for the complete torque loss series.

3.1.7.3. The mechanical torque losses and (if applicable) electrical power consumption shall be calculated for each of the measurements as followed:

▼M3

$$T_{loss} = T_{1,in}(n_{in}, T_{in,gear})$$

▼B

$$P_{lel} = I * U$$

It is allowed to subtract influences caused by the test rig setup from the torque losses (3.1.2.2.).

3.1.7.4. The mechanical torque losses and (if applicable) electrical power consumption from the two sets shall be averaged (arithmetic mean values).

▼B

3.1.7.5. The deviation between the averaged torque losses of the two measurement points for each setting shall be below ± 5 % of the average or ± 1 Nm, whichever value is larger. Then, the arithmetic average of the two averaged power values shall be taken.

3.1.7.6. If the deviation is higher, the largest averaged torque loss value shall be taken or the test shall be repeated for the gear.

3.1.7.7. The deviation between the averaged electric power consumption (voltage * current) values of the two measurements for each measurement setting shall be below ± 10 % of the average or ± 5 W, whichever value is larger. Then, the arithmetic average of the two averaged power values shall be taken.

3.1.7.8. If the deviation is higher, the set of averaged voltage and current values giving the largest averaged power consumption shall be taken, or the test shall be repeated for the gear.

3.1.8. Measurement uncertainty

The part of the calculated total uncertainty $U_{T,loss}$ exceeding 0,3 Nm shall be added to T_{loss} for the reported torque loss $T_{loss,rep}$. If $U_{T,loss}$ is smaller than 0,3 Nm, then $T_{loss,rep} = T_{loss}$.

$$T_{loss,rep} = T_{loss} + MAX\ (0,\ (U_{T,loss} - 0{,}3\ Nm))$$

The total uncertainty $U_{T,loss}$ of the torque loss shall be calculated based on the following parameters:

(1) Temperature effect

(2) Parasitic loads

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

The total uncertainty of the torque loss ($U_{T,loss}$) is based on the uncertainties of the sensors at 95 % confidence level. The calculation shall be done as the square root of the sum of squares ('Gaussian law of error propagation').

$$U_{T,loss} = U_{T,in} = 2 \times \sqrt{u_{TKC}^2 + u_{TK0}^2 + u_{cal}^2 + u_{para}^2}$$

$$u_{TKC} = \frac{1}{\sqrt{3}} \times \frac{w_{tkc}}{K_{ref}} \times \Delta K \times T_c$$

$$u_{TK0} = \frac{1}{\sqrt{3}} \times \frac{w_{tk0}}{K_{ref}} \times \Delta K \times T_n$$

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

$$u_{para} = \frac{1}{\sqrt{3}} \times w_{para} \times T_n$$

$$w_{para} = sens_{para} * i_{para}$$

▼B

where:

T_{loss} = Measured torque loss (uncorrected) [Nm]

$T_{loss,rep}$ = Reported torque loss (after uncertainty correction) [Nm]

$U_{T,loss}$ = Total expanded uncertainty of torque loss measurement at 95 % confidence level [Nm]

$U_{T,in}$ = Uncertainty of input torque loss measurement [Nm]

u_{TKC} = Uncertainty by temperature influence on current torque signal [Nm]

w_{tkc} = Temperature influence on current torque signal per K_{ref}, declared by sensor manufacturer [%]

u_{TK0} = Uncertainty by temperature influence on zero torque signal (related to nominal torque) [Nm]

w_{tk0} = Temperature influence on zero torque signal per K_{ref} (related to nominal torque), declared by sensor manufacturer [%]

K_{ref} = Reference temperature span for u_{TKC} and u_{TK0}, w_{tk0} and w_{tkc}, declared by sensor manufacturer [K]

ΔK = Difference in sensor temperature between calibration and measurement [K]. If the sensor temperature cannot be measured, a default value of $\Delta K = 15$ K shall be used.

T_c = Current/measured torque value at 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)

u_{para} = Uncertainty by parasitic loads [Nm]

w_{para} = $sens_{para} * i_{para}$

Relative influence of forces and bending torques caused by misalignment

$sens_{para}$ = Maximum influence of parasitic loads for specific torque sensor declared by sensor manufacturer [%]; if no specific value for parasitic loads is declared by the sensor manufacturer, the value shall be set to 1,0 %

▼B

i_{para} = Maximum influence of parasitic loads for specific torque sensor depending on test setup (A/B/C, as defined below).

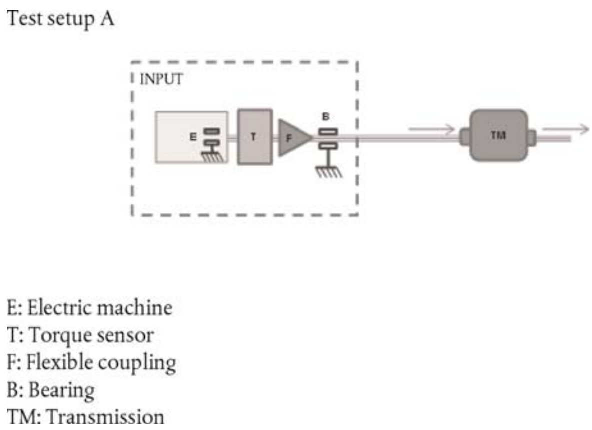
= **A)** 10 % in case of bearings isolating the parasitic forces in front of and behind the sensor and a flexible coupling (or cardan shaft) installed functionally next to the sensor (downstream or upstream); furthermore, these bearings can be integrated in a driving/braking machine (e.g. electric machine) and/or in the transmission as long as the forces in the machine and/or transmission are isolated from the sensor. See figure 1.

Figure 1

▼M3

Example of test setup A for Option 1

▼B



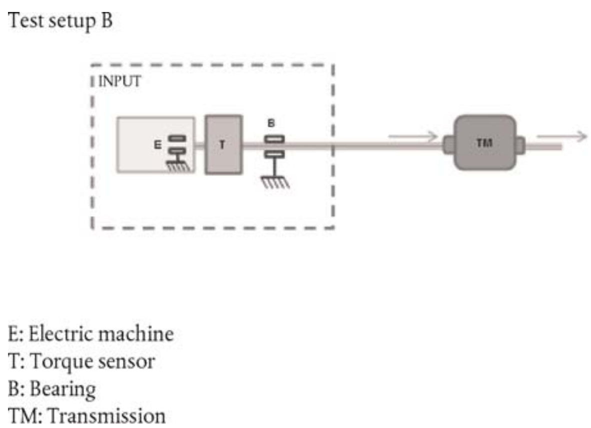
= **B)** 50 % in case of bearings isolating the parasitic forces in front of and behind the sensor and no flexible coupling installed functionally next to the sensor; furthermore, these bearings can be integrated in a driving/braking machine (e.g. electric machine) and/or in the transmission as long as the forces in the machine and/or transmission are isolated from the sensor. See figure 2.

Figure 2

▼M3

Example of test setup B for Option 1

▼B



▼B

= **C)** 100 % for other setups

▼M3

A test setup for a transmission with integrated differential for front-wheel drive operation consists of a dynamometer on the transmission input side and at least one dynamometer on the transmission output side(s). Torque measuring devices shall be installed on the transmission input- and output- side(s). For test setups with only one dynamometer on the output side, the free rotating end of the transmission with integrated differential shall be rotatably locked to the other end on the output side (e.g. by an activated differential lock or by means of any other mechanical differential lock implemented only for the measurement).

The graduation of the factor i_{para} for the maximum influence of parasitic loads for specific torque sensor is equal to the above described cases (A/B/C).

Figure 2A

Example of test setup A for Option 1 for a transmission with integrated differential (e.g. for front-wheel drive operation)

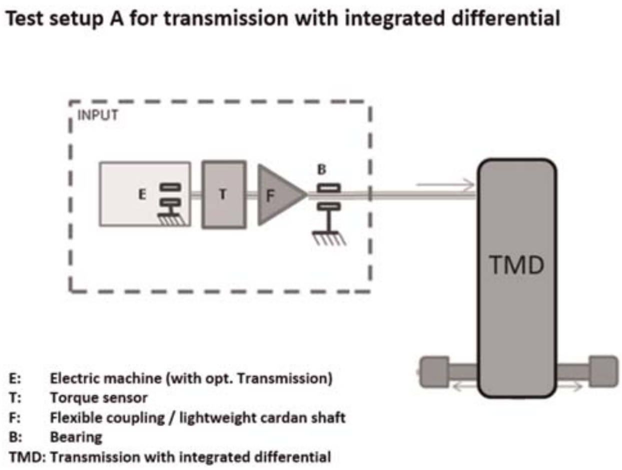
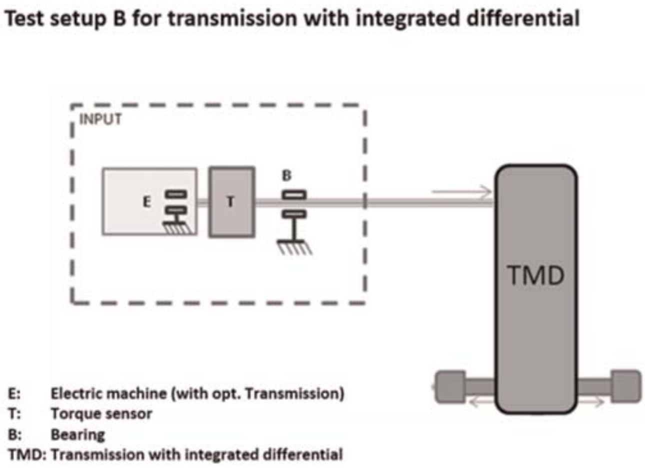


Figure 2B

Example of test setup B for Option 1 for a transmission with integrated differential (e.g. for front-wheel drive operation)



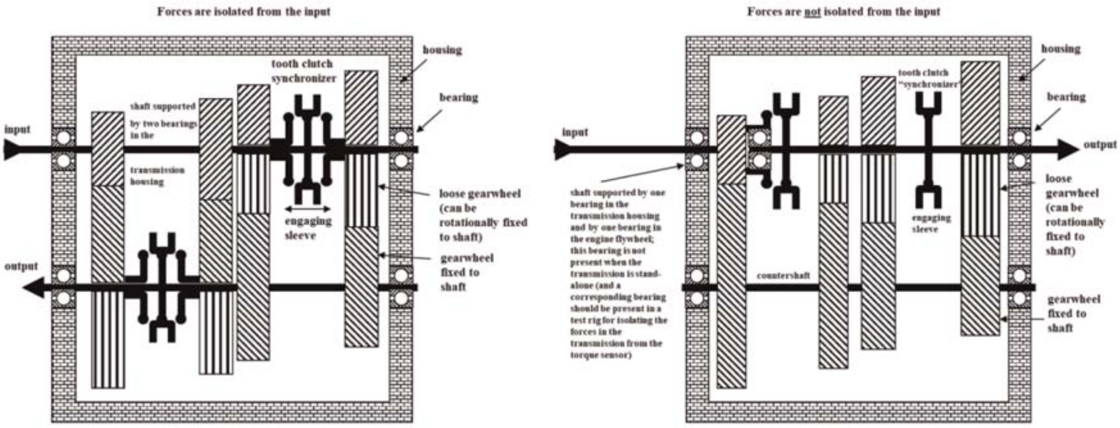
▼**M3**

The manufacturer may adapt the test setups A and B based upon good engineering judgement and in agreement with the approval authority, e.g. in the case of practical test setup reasons. In the case of such a deviation, the reason and alternative setup shall be clearly specified in the test report.

It is allowed to perform the test without a separate bearing unit on the test rig at the transmission input/output side if the transmission shaft on which the torque is measured is supported by two bearings in the transmission housing which are able to absorb radial and axial forces caused by the gearsets.

Figure 2C

Example where the forces in the transmission are isolated and not isolated from the input:



▼**B**

3.2. Option 2: Measurement of the torque independent losses, measurement of the torque loss at maximum torque and interpolation of the torque dependent losses based on a linear model

Option 2 describes the determination of the torque loss by a combination of measurements and linear interpolation. Measurements shall be performed for the torque independent losses of the transmission and for one load point of the torque dependent losses (maximum input torque). Based on the torque losses at no load and at maximum input torque, the torque losses for the input torques in between shall be calculated with the torque loss coefficient f_{Tlimo}.

The torque loss $T_{l,in}$ on the input shaft of the transmission shall be calculated by

▼**M3**

$$T_{l,in}(n_{in},T_{in},gear) = T_{l,in,min\_loss} + f_{Tlino} \times T_{in} + T_{l,in,min\_el} + f_{el\_corr} \times T_{in} + f_{loss_{tcc}} \times T_{in}$$

▼**B**

The torque loss coefficient based on the linear model f_{Tlimo} shall be calculated by

$$f_{Tlimo} = \frac{T_{l,maxT} - T_{l,in,min\_loss}}{T_{in,maxT}}$$

where:

$T_{l,in}$ = Torque loss related to input shaft [Nm]

▼B

T_{l,in,min_loss} = Drag torque loss at transmission input, measured with free rotating output shaft from testing without load [Nm]

n_{in} = Speed at the input shaft [rpm]

f_{Tlimo} = Torque loss coefficient based on linear model [-]

T_{in} = Torque at the input shaft [Nm]

$T_{in,maxT}$ = Maximum tested torque at the input shaft (normally 100 % input torque, refer to 3.2.5.2. and 3.4.4.) [Nm]

$T_{l,maxT}$ = Torque loss related to input shaft with $T_{in} = T_{in,maxT}$

f_{el_corr} = Loss correction for electric power loss level depending on input torque [-]

$T_{l,in,el}$ = Additional torque loss on input shaft by electric consumers [Nm]

T_{l,in,min_el} = Additional torque loss on input shaft by electric consumers corresponding to minimum electric power [Nm]

▼M3

The correction factor for the torque dependent electric torque losses f_{el_corr}, the torque loss at the input shaft of the transmission caused by the power consumption of transmission electric auxiliary $T_{l,in,el}$ and the loss correction factor f_{loss_tcc} for slipping TC lock-up clutch as defined in point 2(16) or slipping input side clutch as defined in 2(20) shall be calculated as described in point 3.1.

▼B

3.2.1. The torque losses shall be measured in accordance with the procedure described in the following.

3.2.1.1. General requirements:

As specified for Option 1 in 3.1.2.1.

3.2.1.2. Differential measurements:

As specified for Option 1 in 3.1.2.2.

▼B

3.2.1.3. Run-in

As specified for Option 1 in 3.1.2.3.

3.2.1.4. Pre-conditioning

As specified for Option 3 in 3.3.2.1.

3.2.1.5. Test conditions

3.2.1.5.1. Ambient temperature

As specified for Option 1 in 3.1.2.5.1.

3.2.1.5.2. Oil temperature

As specified for Option 1 in 3.1.2.5.2.

3.2.1.5.3. Oil quality / Oil viscosity

As specified for Option 1 in 3.1.2.5.3 and 3.1.2.5.4.

3.2.1.5.4. Oil level and conditioning

As specified for Option 3 in 3.3.3.4.

3.2.2. Installation

As specified for Option 1 in 3.1.3. for the measurement of the torque independent losses.

As specified for Option 3 in 3.3.4. for the measurement of the torque dependent losses.

3.2.3. Measurement equipment

As specified for Option 1 in 3.1.4. for the measurement of the torque independent losses.

As specified for Option 3 in 3.3.5. for the measurement of the torque dependent losses.

3.2.4. Measurement signals and data recording

As specified for Option 1 in 3.1.5 for the measurement of the torque independent losses.

As specified for Option 3 in 3.3.7 for the measurement of the torque dependent losses.

3.2.5. Test procedure

The torque loss map to be applied to the simulation tool contains the torque loss values of a transmission depending on rotational input speed and input torque.

To determine the torque loss map for a transmission, the basic torque loss map data shall be measured and calculated as specified in this paragraph. The torque loss results shall be complemented in accordance with 3.4 and formatted in accordance with Appendix 12 for the further processing by the simulation tool.

▼B

3.2.5.1. The torque independent losses shall be determined by the procedure described in 3.1.1. for the torque independent losses for Option 1 only for the low loss level setting of electric and hydraulic consumers.

3.2.5.2. Determine the torque dependent losses for each of the gears using the procedure described for Option 3 in 3.3.6., diverging in the applicable torque range:

Torque range:

The torque losses for each gear shall be measured at 100 % of the maximum transmission input torque per gear.

In the case the output torque exceeds 10 kNm (for a theoretical loss free transmission) or the input power exceeds the specified maximum input power, point 3.4.4. shall apply.

3.2.6. Measurement validation

As specified for Option 3 in 3.3.8.

3.2.7. Measurement uncertainty

As specified for Option 1 in 3.1.8. for the measurement of the torque independent losses.

As specified for Option 3 in 3.3.9. for the measurement of the torque dependent loss.

3.3. Option 3: Measurement of the total torque loss.

Option 3 describes the determination of the torque loss by full measurement of the torque dependent losses including the torque independent losses of the transmission.

3.3.1. General requirements

As specified for Option 1 in 3.1.2.1.

3.3.1.1 Differential measurements:

As specified for Option 1 in 3.1.2.2.

3.3.2. Run-in

As specified for Option 1 in 3.1.2.3.

3.3.2.1 Pre-conditioning

As specified for Option 1 in 3.1.2.4. with an exception for the following:

The pre-conditioning shall be performed on the direct drive gear without applied torque to the output shaft or target torque on the output shaft set to zero. If the transmission is not equipped with a direct drive gear, the gear with the ratio closest to 1:1 shall be used.

or

The requirements as specified in 3.1.2.4. shall apply, with an exception for the following:

▼B

The pre-conditioning shall be performed on the direct drive gear without applied torque to the output shaft or the torque on the output shaft being within +/- 50 Nm. If the transmission is not equipped with a direct drive gear, the gear with the ratio closest to 1:1 shall be used.

or, if the test rig includes a (master friction) clutch at the input shaft:

The requirements as specified in 3.1.2.4. shall apply, with an exception for the following:

The pre-conditioning shall be performed on the direct drive gear without applied torque to the output shaft or without applied torque to the input shaft. If the transmission is not equipped with a direct drive gear, the gear with the ratio closest to 1:1 shall be used.

The transmission would then be driven from the output side. Those proposals could also be combined.

3.3.3. Test conditions

3.3.3.1. Ambient temperature

As specified for Option 1 in 3.1.2.5.1.

3.3.3.2. Oil temperature

As specified for Option 1 in 3.1.2.5.2.

3.3.3.3. Oil quality / Oil viscosity

As specified for Option 1 in 3.1.2.5.3 and 3.1.2.5.4.

3.3.3.4. Oil level and conditioning

The requirements as specified in 3.1.2.5.5. shall apply, diverging in the following:

The test point for the external oil conditioning system is specified as follows:

(1) highest indirect gear,

▼M3

(2) input speed = minimum of 60 %, not higher than 80 % of the maximum input speed,

▼B

(3) input torque = maximum input torque for the highest indirect gear

3.3.4. Installation

The test rig shall be driven by electric machines (input and output).

▼M3

Torque sensors shall be installed at the input and output side(s) of the transmission.

▼B

Other requirements as specified in 3.1.3. shall apply.

▼B

3.3.5. Measurement equipment

For the measurement of the torque independent losses, the measurement equipment requirements as specified for Option 1 in 3.1.4. shall apply.

For the measurement of the torque dependent losses, the following requirements shall apply:

The torque sensor measurement uncertainty shall be below 5 % of the measured torque loss or 1 Nm (whichever value is larger).

The use of torque sensors with higher measurement uncertainties is allowed if the parts of the uncertainty exceeding 5 % or 1 Nm can be calculated and the smaller of those parts is added to the measured torque loss.

The torque measurement uncertainty shall be calculated and included as described under 3.3.9.

Other measurement equipment requirements as specified for Option 1 in 3.1.4. shall apply.

3.3.6. Test procedure

3.3.6.1. Zero torque signal compensation:

As specified in 3.1.6.1.

▼M3

3.3.6.2. Speed range

The torque loss shall be measured for the following speed points (speed of the input shaft): 600, 900, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000 rpm and multiples of 10 of these values up to the maximum speed per gear according to the specifications of the transmission or the last speed point before the defined maximum speed. It is permitted to measure additional intermediate speed points.

The speed ramp (time for the change between two speed points) shall not exceed 20 seconds.

3.3.6.3. Torque range

For each speed point the torque loss shall be measured for the following input torques: 0 (free rotating output shaft), 200, 400, 600, 900, 1 200, 1 600, 2 000, 2 500, 3 000, 3 500, 4 000, […] Nm up to the maximum input torque per gear in accordance with the specifications of the transmission or the last torque point before the defined maximum torque and / or the last torque point before the output torque of 10 kNm. It is permitted to measure additional intermediate torque points. If the torque range is too small, additional torque points are required, so that at least 5 equally spaced torque points shall be measured. The intermediate torque points may be adjusted to the nearest multiple of 50 Nm.

In the case the output torque exceeds 10 kNm (for a theoretical loss free transmission) or the input power exceeds the specified maximum input power, point 3.4.4. shall apply.

▼M3

The torque ramp (time for the change between two torque points) shall not exceed 15 seconds (180 seconds for option 2).

To cover the complete torque range of a transmission in the above defined map, different torque sensors with limited measurement ranges may be used on the input/output side. Therefore the measurement may be divided into sections using the same set of torque sensors. The overall torque loss map shall be composed of these measurement sections.

▼B

3.3.6.4. Measurement sequence

3.3.6.4.1. The measurements shall be performed beginning with the lowest up to the highest speed.

▼M3

3.3.6.4.2. The input torque shall be varied according to the above defined torque points from the lowest to the highest torque which is covered by the current torque sensors for each speed point.

▼B

3.3.6.4.3. ►M3 For each speed and torque point a minimum of 5-second stabilisation time within the temperature limits defined in 3.3.3. is required. ◄ If needed, the stabilization time may be extended by the manufacturer to maximum 60 seconds (maximum 180 seconds for option 2). Oil and ambient temperatures shall be recorded during the stabilization.

▼M3

3.3.6.4.3.1. After the stabilisation time, the torque loss should be constant at the actual measured speed point over time. If so, the measurement signals listed in 3.3.7. shall be recorded for a minimum of 5 seconds but for no longer than 15 seconds. If the torque loss is not constant at the actual measured speed point over time, e.g. by intended periodic variation of the torque losses caused by active or passive means of control, the manufacturer shall use the testing time required to get a reproducible and representative result.

▼B

3.3.6.4.4. The measurement set shall be performed two times in total. For that purpose, sequenced repetition of sections using the same set of torque sensors is allowed.

3.3.7. Measurement signals and data recording

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

(1) Input and output torques [Nm]

(2) Input and output rotational speeds [rpm]

(3) Ambient temperature [°C]

(4) Oil temperature [°C]

▼B

If the transmission is equipped with a shift and/or clutch system that is controlled by hydraulic pressure or with a mechanically driven smart lubrication system, additionally to be recorded:

(5) Oil pressure [kPa]

If the transmission is equipped with transmission electric auxiliary, additionally to be recorded:

(6) Voltage of transmission electric auxiliary [V]

(7) Current of transmission electric auxiliary [A]

For differential measurements for compensation of influences by test rig setup, additionally to be recorded:

(8) Test rig bearing temperature [°C]

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

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

3.3.8. Measurement validation

▼M3

3.3.8.1. The arithmetic mean values of torque, speed, if applicable voltage and current for the measurement for a minimum of 5 seconds but for no longer than 15 seconds shall be calculated for each of the two measurements. If the torque loss is not constant at the actual measured speed point over time, e.g. by intended periodic variation of the torque losses caused by active or passive means of control, the manufacturer shall use the testing time required to get a reproducible and representative result.

▼B

3.3.8.2. The measured and averaged speed at the input shaft shall be below ± 5 rpm of the speed set point for each measured operating point for the complete torque loss series. ►M1 The measured and averaged torque at the input shaft shall be below ± 5 Nm or ± ►M3 1,0 % ◄ of the torque set point whichever value is larger for each measured operating point for the complete torque loss series. ◄

▼M3

3.3.8.3. The mechanical torque losses and (if applicable) electrical power consumption shall be calculated for each of the measurements as followed:

$$T_{loss} = T_{in} \times (1 + f_{loss_{tcc}}) - \frac{T_{out}}{i_{gear}} + \frac{\mathbf{I} \times \mathbf{U}}{(\mathbf{0{,}7} \times \mathbf{n_{in}} \times \frac{\mathbf{2\pi}}{\mathbf{60}})}$$

In the case of a transmission with integrated differential and a dynamometer on each output shaft, the total mechanical torque loss (T_{loss}) shall be calculated by:

▼M3

$$T_{loss} = T_{in} \times (1 + f_{loss_{tcc}}) - \frac{T_{out\_1}}{i_{gear}} - \frac{T_{out\_2}}{i_{gear}} + \frac{I \times U}{(0{,}7 \times n_{in} \times \frac{2\pi}{60})}$$

The correction factor for the loss correction f_{loss_tcc} for slipping TC lock-up clutch or slipping input side clutch in accordance with the definitions (16) and (20) shall be calculated as described in point 3.1.

It is allowed to subtract influences caused by the test rig setup from the torque losses (in accordance with section 3.1.2.2.).

▼B

3.3.8.4. The mechanical torque losses and (if applicable) electrical power consumption from the two sets shall be averaged (arithmetic mean values).

3.3.8.5. The deviation between the averaged torque losses of the two measurement sets shall be below ± 5 % of the average or ± 1 Nm (whichever value is larger). The arithmetic average of the two averaged torque loss values shall be taken. If the deviation is higher, the largest averaged torque loss value shall be taken or the test shall be repeated for the gear.

3.3.8.6. The deviation between the averaged electric power consumption (voltage*current) values of the two measurement sets shall be below ± 10 % of the average or ± 5 W, whichever value is larger. Then, the arithmetic average of the two averaged power values shall be taken.

3.3.8.7. If the deviation is higher, the set of averaged voltage and current values giving the largest averaged power consumption shall be taken, or the test shall be repeated for the gear.

3.3.9. Measurement uncertainty

The part of the calculated total uncertainty $U_{T,loss}$ exceeding 5 % of T_{loss} or 1 Nm ($\Delta U_{T,loss}$), whichever value of $\Delta U_{T,loss}$ is smaller, shall be added to T_{loss} for the reported torque loss $T_{loss,rep}$. If $U_{T,loss}$ is smaller than 5 % of T_{loss} or 1 Nm, then $T_{loss,rep} = T_{loss}$.

$$T_{loss,rep} = T_{loss} + MAX\ (0,\ \Delta U_{T,loss})$$

$$\Delta U_{T,loss} = MIN\ ((U_{T,loss} - 5\ \% * T_{loss}),\ (U_{T,loss} - 1\ Nm))$$

For each measurement set, the total uncertainty $U_{T,loss}$ of the torque loss shall be calculated based on the following parameters:

▼B

(1) Temperature effect

(2) Parasitic loads

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

The total uncertainty of the torque loss ($U_{T,loss}$) is based on the uncertainties of the sensors at 95 % confidence level. The calculation shall be done as the square root of the sum of squares ('Gaussian law of error propagation').

$$U_{T,loss} = \sqrt{U_{T,in}{}^2 + \left(\frac{U_{T,out}}{i_{gear}}\right)^2}$$

$$U_{T,in/out} = 2 \times \sqrt{u_{TKC}^2 + u_{TK0}^2 + u_{cal}^2 + u_{para}^2}$$

$$u_{TKC} = \frac{1}{\sqrt{3}} \times \frac{w_{tkc}}{K_{ref}} \times \Delta K \times T_c$$

$$u_{TK0} = \frac{1}{\sqrt{3}} \times \frac{w_{tk0}}{K_{ref}} \times \Delta K \times T_n$$

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

$$u_{para} = \frac{1}{\sqrt{3}} \times w_{para} \times T_n$$

$$w_{para} = sens_{para} * i_{para}$$

where:

T_{loss} = Measured torque loss (uncorrected) [Nm]

$T_{loss,rep}$ = Reported torque loss (after uncertainty correction) [Nm]

$U_{T,loss}$ = Total expanded uncertainty of torque loss measurement at 95 % confidence level [Nm]

$u_{T,in/out}$ = Uncertainty of input/output torque loss measurement separately for input and output torque sensor[Nm]

i_{gear} = Gear ratio [-]

u_{TKC} = Uncertainty by temperature influence on current torque signal [Nm]

w_{tkc} = Temperature influence on current torque signal per K_{ref}, declared by sensor manufacturer [%]

▼B

u_{TK0} = Uncertainty by temperature influence on zero torque signal (related to nominal torque) [Nm]

w_{tk0} = Temperature influence on zero torque signal per K_{ref} (related to nominal torque), declared by sensor manufacturer [%]

K_{ref} = Reference temperature span for u_{TKC} and u_{TK0}, w_{tk0} and w_{tkc}, declared by sensor manufacturer [K]

ΔK = Difference in sensor temperature between calibration and measurement [K]. If the sensor temperature cannot be measured, a default value of ΔK = 15 K shall be used.

T_c = Current/measured torque value at 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)

u_{para} = Uncertainty by parasitic loads [Nm]

w_{para} = $sens_{para} * i_{para}$

Relative influence of forces and bending torques caused by misalignment [%]

$sens_{para}$ = Maximum influence of parasitic loads for specific torque sensor declared by sensor manufacturer [%]; if no specific value for parasitic loads is declared by the sensor manufacturer, the value shall be set to 1,0 %

i_{para} = Maximum influence of parasitic loads for specific torque sensor depending on test setup (A/B/C, as defined below).

= **A)** 10 % in case of bearings isolating the parasitic forces in front of and behind the sensor and a flexible coupling (or cardan shaft) installed functionally next to the sensor (downstream or upstream); furthermore, these bearings can be integrated in a driving/braking machine (e.g. electric machine) and/or in the transmission as long as the forces in the machine and/or transmission are isolated from the sensor. See figure 3.

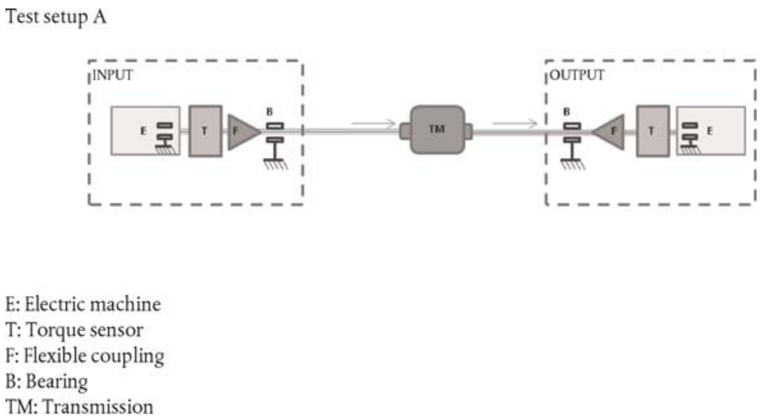
▼B

Figure 3

▼M3

Example of test setup A for Option 3

▼B



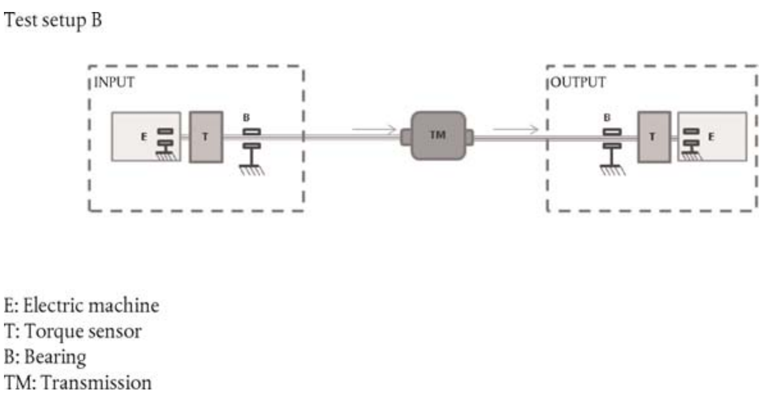
= **B)** 50 % in case of bearings isolating the parasitic forces in front of and behind the sensor and no flexible coupling installed functionally next to the sensor; furthermore, these bearings can be integrated in a driving/braking machine (e.g. electric machine) and/or in the transmission as long as the forces in the machine and/or transmission are isolated from the sensor. See figure 4.

Figure 4

▼M3

Example of test setup B for Option 3

▼B



= **C)** 100 % for other setups

▼M3

A test set-up for the transmission with integrated differential for front-wheel drive operation consists of a dynamometer on the transmission input side and at least one dynamometer on the transmission output side(s). Torque measuring devices shall be installed on the transmission input and output side(s). For test setups with only one

▼M3

dynamometer on the output side, the free rotating end of the transmission with integrated differential shall be rotatably locked to the other end on the output side (e.g. by an activated differential lock or by means of any other mechanical differential lock implemented only for the measurement).

The graduation of the factor i_{para} for the maximum influence of parasitic loads for the specific torque sensors is equal to the cases described above (A/B/C).

Figure 5

Example of test setup A for a transmission with integrated differential (e.g. for front-wheel drive operation)

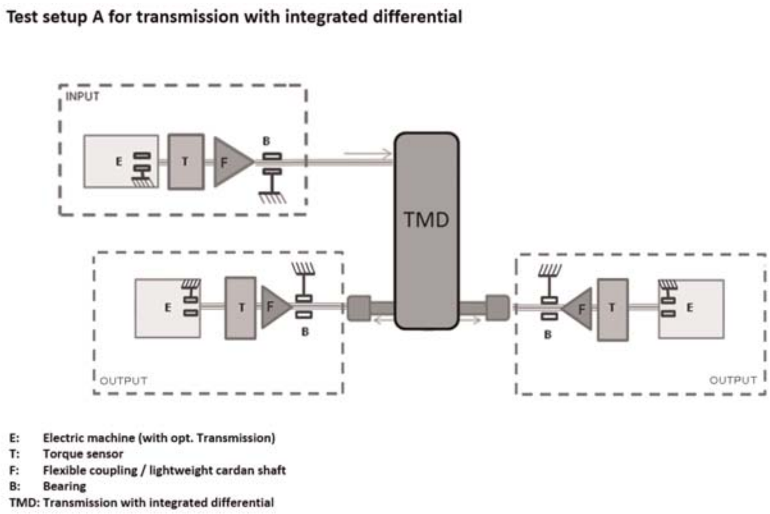
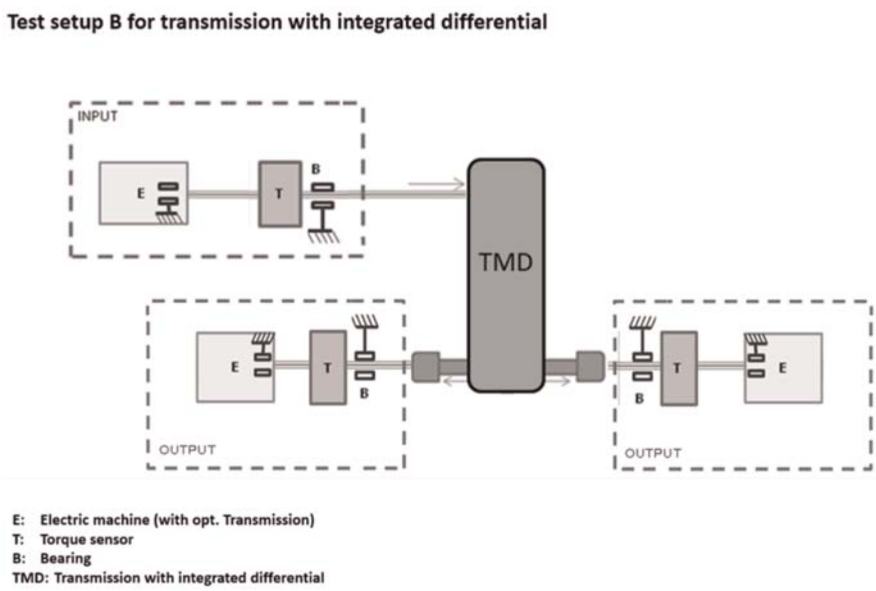


Figure 6

Example of test setup B for a transmission with integrated differential (e.g. for front-wheel drive operation)



▼**M3**

In the case of a dynamometer on each output shaft, the total uncertainty of the torque loss ($U_{T,loss}$) shall be calculated by:

$$U_{T,loss} = \sqrt{U_{T,in}^2 + \left(\frac{U_{T,out1}}{i_{gear}}\right)^2 + \left(\frac{U_{T,out2}}{i_{gear}}\right)^2}$$

The manufacturer may adapt the test setups A and B based upon good engineering judgement and in agreement with the approval authority, e.g. in the case of practical test setup reasons. In the case of such a deviation, the reason and alternative setup shall be clearly specified in the test report.

It is allowed to perform the test without a separate bearing unit on the test rig at the transmission input/output side, if the transmission shaft on which the torque is measured is supported by two bearings in the transmission housing which are able to absorb radial and axial forces caused by the gearsets (see figure 2C in 3.1.8.).

▼**B**

3.4. Complement of input files for the simulation tool

►**M3** For each gear a torque loss map covering the defined input speed and input torque points shall be determined with one of the specified testing options or standard torque loss values. ◄ For the input file for the simulation tool, this basic torque loss map shall be complemented as described in the following:

3.4.1. ►**M3** In the cases the highest tested input speed was the last speed point below the defined maximum permissible transmission speed, an extrapolation of the torque loss shall be applied up to the maximum speed with linear regression based on the two last measured speed points. ◄

3.4.2. ►**M3** In the cases the highest tested input torque was the last torque point below the defined maximum permissible transmission torque, an extrapolation of the torque loss shall be applied up to the maximum torque with linear regression based on the two last measured torque points for the corresponding speed point. ◄ In order to handle engine torque tolerances, etc., the simulation tool will, if required, perform an extrapolation of the torque loss for input torques up to 10 % above said defined maximum permissible transmission torque.

3.4.3. In the case of extrapolation of the torque loss values for maximum input speed and maximum input torque at the same time, the torque loss for the combined point of highest speed and highest torque shall be calculated with two-dimensional linear extrapolation.

3.4.4. If the maximum output torque exceeds 10 kNm (for a theoretical loss free transmission), and/or for all speed and torque points with input power higher than the specified maximum input power, the manufacturer may choose to take the torque loss values for all torques higher than 10 kNm, and/or for all speed and torque points with input power higher than the specified maximum input power, respectively, from one of:

▼B

(1) Calculated fallback values (Appendix 8)

(2) Option 1

(3) Option 2 or 3 in combination with a torque sensor for higher output torques (if required)

For cases (i) and (ii) in Option 2, the torque losses at load shall be measured at the input torque that corresponds to output torque 10 kNm and/or the specified maximum input power.

▼M3

3.4.5. For speeds below the defined minimum speed and the additional input speed step of 0 rpm, the reported torque losses determined for the minimum speed point shall be copied.

▼B

3.4.6. To cover the range of negative input torques during vehicle coasting conditions, the torque loss values for positive input torques shall be copied for the related negative input torques.

3.4.7. Upon agreement of an approval authority, the torque losses for the input speeds below 1 000 rpm may be replaced by the torque losses at 1 000 rpm when the measurement is technically not possible.

▼M3

3.4.8. If the measurement of speed points is technically not possible (e.g. due to natural frequency), the manufacturer may, in agreement with the approval authority, calculate the torque losses by interpolation or extrapolation (limited to max. 1 speed point per gear).

▼B

3.4.9. The torque loss map data shall be formatted and saved as specified in Appendix 12 to this Annex.

▼M3

4. Testing procedure for 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 v (= 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)

▼M3

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 possible only 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. In the case of measurements together with a mechanical transmission, the speed ratio v and all corresponding values for step widths as well as limits shall be adjusted by taking the mechanical transmission ratio into account.

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 in accordance with 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 $v \leq 0{,}95$ (= vehicle propulsion mode).

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

▼B

Table 1

Default values for $v \geq 1{,}00$

v	μ	$T_{pum1000}$
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	– 1 122,00
3,500	0,9991	– 1 648,00
4,000	0,9990	– 2 326,00
4,500	0,9989	– 3 182,00
5,000	0,9988	– 4 242,00

▼B

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 °C + 7/– 3 K.

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

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

In case the TC characteristics are measured separately form 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.

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 ►M3 IATF ◄ 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.

▼B

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 ± 1,5 K.

The uncertainty of the temperature sensors for the measurement of the oil temperature shall not exceed ± 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 v 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 $v = 0$ and a value of $v < 0,95$ have to be covered by the measurement.

4.1.7.2.5. ►M3 For each point a minimum of 3-second stabilisation time within the temperature limits defined in point 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.

▼M3

4.1.7.2.6. For each point the signals specified in 4.1.8. shall be recorded for the test point for a minimum of 3 seconds but for no longer than 15 seconds.

▼B

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 ± 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 $T_{c,pum}$

▼B

— 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.

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

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)

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

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

▼B

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

$$T_{pum1000} = (T_{c,pum} - \Delta U_{T,pum}) \times \left(\frac{1\ 000\ rpm}{n_{pum}}\right)^2$$

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]
$T_{pum1000}$	=	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

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).

▼B

4.2.7.2.2. The speed ratio v 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 v 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. ►M3 For each point a minimum of 5-second stabilisation time within the temperature limits defined in point 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.

▼M3

4.2.7.2.6. For each point the values specified in 4.2.8. shall be recorded for the test point for a minimum of 5 seconds but for no longer than 15 seconds.

▼B

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.

5. ►M3 Testing procedure for other torque transferring components (OTTC) ◄

The scope of this section includes engine retarders, transmission retarders, driveline retarders, and components that are treated in the simulation tool as a retarder. These components include vehicle starting devices like a single wet transmission input clutch or hydro-dynamic clutch.

5.1. Methods for establishing retarder drag losses

The retarder drag torque loss is a function of the retarder rotor speed. Since the retarder can be integrated in different parts of the vehicle driveline, the retarder rotor speed depends on the drive part (= speed reference) and step-up ratio between drive part and retarder rotor as shown in Table 2.

▼B

Table 2

Retarder rotor speeds

Configuration	Speed reference	Retarder rotor speed calculation
A. Engine Retarder	Engine Speed	$n_{retarder} = n_{engine} * i_{step\text{-}up}$
B. Transmission Input Retarder	Transmission Input Shaft Speed	$n_{retarder} = n_{transm.input} * i_{step\text{-}up}$ $= n_{transm.output} * i_{transm} * i_{step\text{-}up}$
C. Transmission Output Retarder or Axlegear Input Retarder	Transmission Output Shaft Speed or Axlegear Input Shaft Speed	$n_{retarder} = n_{transm.output} \times i_{step\text{-}up}$

▼M3 (row C)

▼B

where:

$i_{step\text{-}up}$ = step-up ratio = retarder rotor speed/drive part speed

i_{transm} = transmission ratio = transmission input speed/transmission output speed

Retarder configurations that are integrated in the engine and cannot be separated from the engine shall be tested in combination with the engine. This section does not cover these non-separable engine integrated retarders.

Retarders that can be disconnected from the driveline or the engine by any kind of clutch are considered to have zero rotor speed in disconnected condition and therefore have no power losses.

The retarder drag losses shall be measured with one of the following two methods:

(1) Measurement on the retarder as a stand-alone unit

(2) Measurement in combination with the transmission

5.1.1. General requirements

In case the losses are measured on the retarder as stand-alone unit, the results are affected by the torque losses in the bearings of the test setup. It is permitted to measure these bearing losses and subtract them from the retarder drag loss measurements.

The manufacturer shall guarantee that the retarder used for the measurements is in accordance with the drawing specifications for series production retarders.

Modifications to the retarder to meet the testing requirements of this Annex, e.g. for the inclusion of measurement sensors or the adaption of an external oil conditioning systems are permitted.

▼B

Based on the family described in Appendix 6 to this Annex, measured drag losses for transmissions with retarder can be used for the same (equivalent) transmission without retarder.

The use of the same transmission unit for measuring the torque losses of variants with and without retarder is 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.

5.1.2. Run-in

On request of the applicant a run-in procedure may be applied to the retarder. The following provisions shall apply for a run-in procedure.

5.1.2.1 If the manufacturer applies a run-in procedure to the retarder, the run-in time for the retarder shall not exceed 100 hours at zero retarder apply torque. Optionally a share of a maximum of 6 hours with retarder apply torque may be included.

5.1.3. Test conditions

5.1.3.1. Ambient temperature

The ambient temperature during the test shall be in a range of 25 °C ± 10 K.

The ambient temperature shall be measured 1 m laterally from the retarder.

5.1.3.2. Ambient pressure

For magnetic retarders the minimum ambient pressure shall be 899 hPa according to International Standard Atmosphere (ISA) ISO 2533.

5.1.3.3. Oil or water temperature

For hydrodynamic retarders:

Except for the fluid, no external heating is allowed.

In case of testing as stand-alone unit, the retarder fluid temperature (oil or water) shall not exceed 87 °C.

In case of testing in combination with transmission, the oil temperature limits for transmission testing shall apply.

5.1.3.4. Oil or water quality

New, recommended first fill oil for the European market shall be used in the test.

For water retarders the water quality shall meet the specifications set out by the manufacturer for the retarder. The water pressure shall be set to a fixed value close to vehicle condition (1 ± 0,2 bar relative pressure at retarder input hose).

▼B

5.1.3.5. Oil viscosity

If several oils are recommended for first fill, they are considered to be equal if the oils have a kinematic viscosity within 50 % of each other at the same temperature (within the specified tolerance band for KV100).

5.1.3.6. Oil or water level

The oil/water level shall meet the nominal specifications for the retarder.

5.1.4. Installation

The electric machine, the torque sensor, and speed sensor shall be mounted at the input side of the retarder or transmission.

The installation of the retarder (and transmission) shall be done with an inclination angle as for installation in the vehicle according to the homologation drawing ± 1° or at 0° ± 1°.

5.1.5. Measurement equipment

As specified for transmission testing in 3.1.4.

5.1.6. Test procedure

5.1.6.1. Zero torque signal compensation:

As specified for transmission testing in 3.1.6.1.

5.1.6.2. Measurement sequence

The torque loss measurement sequence for the retarder testing shall follow the provisions for the transmission testing defined in 3.1.6.3.2. to 3.1.6.3.5.

5.1.6.2.1. Measurement on the retarder as stand-alone unit

When the retarder is tested as stand-alone unit, torque loss measurements shall be conducted using the following speed points:

200, 400, 600, 900, 1 200, 1 600, 2 000, 2 500, 3 000, 3 500, 4 000, 4 500, 5 000, continued up to the maximum retarder rotor speed.

5.1.6.2.2. Measurement in combination with the transmission

5.1.6.2.2.1. In case the retarder is tested in combination with a transmission, the selected transmission gear shall allow the retarder to operate at its maximum rotor speed.

5.1.6.2.2. The torque loss shall be measured at the operating speeds as indicated for the related transmission testing.

5.1.6.2.2.3. Measurement points may be added for transmission input speeds below 600 rpm if requested by the manufacturer.

5.1.6.2.2.4. The manufacturer may separate the retarder losses from the total transmission losses by testing in the order as described below:

▼M1

(1) The load-independent torque loss for the complete transmission including retarder shall be measured as defined in point 3.1. for transmission testing in one of the higher transmission gears:

$$= T_{l,in,withret}$$

▼B

(2) The retarder and related parts shall be replaced with parts required for the equivalent transmission variant without retarder. The measurement of point (1) shall be repeated.

$$= T_{l,in,withoutret}$$

(3) The load-independent torque loss for the retarder system shall be determined by calculating the differences between the two test data sets

$$= T_{l,in,retsys} = T_{l,in,withret} - T_{l,in,withoutret}$$

5.1.7. Measurement signals and data recording

As specified for transmission testing in 3.1.5.

5.1.8. Measurement validation

All recorded data shall be checked and processed as defined for transmission testing in 3.1.7.

5.2. Complement of input files for the simulation tool

5.2.1 Retarder torque losses for speeds below the lowest measurement speed shall be set equal to the measured torque loss at this lowest measurement speed.

5.2.2 In case the retarder losses were separated out from the total losses by calculating the difference in data sets of testing with and without a retarder (see 5.1.6.2.2.4.), the actual retarder rotor speeds depend on the retarder location, and/or selected gear ratio and retarder step-up ratio and thereby may differ from the measured transmission input shaft speeds. The actual retarder rotor speeds relative to the measured drag loss data shall be calculated as described in 5.1. Table 2.

5.2.3 The torque loss map data shall be formatted and saved as specified in Appendix 12 to this Annex.

▼M3

6. Testing procedure for additional drivetrain components (ADC) / drivetrain component with a single speed ratio (e.g. angle drive)

6.1. Methods for establishing losses of a drivetrain component with a single speed ratio

▼M3

The losses of a drivetrain component with a single speed ratio shall be determined using one of the following cases:

6.1.1. Case A: Measurement on a separate drivetrain component with a single speed ratio

For the torque loss measurement of a drivetrain component with a single speed ratio, the three options as defined for the determination of the transmission losses shall apply:

Option 1: Measured torque independent losses and calculated torque dependent losses (Transmission test option 1)

Option 2: Measured torque independent losses and measured torque dependent losses at full load (Transmission test option 2)

Option 3: Measurement under full load points (Transmission test option 3)

The measurement, the validation and the uncertainty calculation of the losses of a drivetrain component with a single speed ratio shall follow the procedure described for the related transmission test option in point 3 diverging in the following requirements:

Measurements shall be performed at 200 rpm and 400 rpm (at the input shaft of the drivetrain component with a single speed ratio) and for the following speed points: 600, 900, 1 200, 1 600, 2 000, 2 500, 3 000, 4 000 rpm and multiples of 10 of these values up to the maximum speed in accordance with specifications of the drivetrain component with a single speed ratio, or the last speed point before the defined maximum speed. It is permitted to measure additional intermediate speed points.

6.1.1.1 Applicable speed range:

6.1.2. Case B: Individual measurement of a drivetrain component with a single speed ratio connected to a transmission

Where the drivetrain component with a single speed ratio is tested in combination with a transmission, the testing shall follow one of the defined options for transmission testing:

Option 1: Measured torque independent losses and calculated torque dependent losses (Transmission test option 1)

Option 2: Measured torque independent losses and measured torque dependent losses at full load (Transmission test option 2)

▼**M3**

Option 3: Measurement under full load points (Transmission test option 3)

6.1.2.1 The manufacturer may separate the losses of a drivetrain component with a single speed ratio from the total transmission losses by testing in the order as described below:

(1) The torque loss for the complete transmission including drivetrain component with a single speed ratio shall be measured as defined for the applicable transmission testing option

$$= T_{l,in,withad}$$

(2) The drivetrain component with a single speed ratio and related parts shall be replaced with parts required for the equivalent transmission variant without drivetrain component with a single speed ratio. The measurement of point (1) shall be repeated.

$$= T_{l,in,withoutad}$$

(3) The torque loss for the drivetrain component system with a single speed ratio shall be determined by calculating the differences between the two test data sets

$$= T_{l,in,adsys} = \max(0, T_{l,in,withad} - T_{l,in,withoutad})$$

6.2. Complement of input files for the simulation tool

6.2.1. Torque losses for speeds below the above defined minimum speed and additionally at input speed point of 0 rpm shall be set equal to the torque loss at the minimum speed.

6.2.2. In the cases the highest tested input speed of the drivetrain component with a single speed ratio was the last speed point below the defined maximum permissible speed of the drivetrain component with a single speed ratio, an extrapolation of the torque loss shall be applied up to the maximum speed with linear regression based on the two last measured speed points.

6.2.3. To calculate the torque loss data for the input shaft of the transmission the drivetrain component with a single speed ratio is to be combined with, linear interpolation and extrapolation shall be used.

▼**B**

7. Conformity of the certified CO_2 emissions and fuel consumption related properties

▼B

7.1. Every transmission, torque converter (TC), other torque transferring components (OTTC) and additional driveline components (ADC) shall be so manufactured as to conform to the approved type with regard to the description as given in the certificate and its annexes. ►M3 The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply to the conformity of production arrangements laid down in Article 31 of Regulation (EU) 2018/858. ◄

7.2 Torque converter (TC), other torque transferring components (OTTC) and additional driveline components (ADC) shall be excluded from the production conformity testing provisions of section 8 to this annex.

7.3 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificates set out in Appendix 1 to this Annex.

7.4 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be assessed in accordance with the specific conditions laid down in this paragraph.

7.5 The manufacturer shall test annually at least the number of transmissions indicated in Table 3 based on the total annual production number of the transmissions produced by the manufacturer. For the purpose of establishing the production numbers, only transmissions which fall under the requirements of this Regulation shall be considered.

7.6 Each transmission which is tested by the manufacturer shall be representative for a specific family. Notwithstanding provisions of the point 7.10., only one transmission per family shall be tested.

7.7 For the total annual production volumes between 1 001 and 10 000 transmissions, the choice of the family for which the tests shall be performed shall be agreed between the manufacturer and the approval authority.

7.8 For the total annual production volumes above 10 000 transmissions, the transmission family with the highest production volume shall always be tested. The manufacturer shall justify (ex. by showing sales numbers) to the approval authority the number of tests which has been performed and the choice of the families. The remaining families for which the tests are to be performed shall be agreed between the manufacturer and the approval authority.

Table 3

Sample size conformity testing

Total annual production of transmissions	Number of tests
0 – 1 000	0
> 1 000-10 000	1
> 10 000-30 000	2
> 30 000	3
> 100 000	4

▼B

7.9. For the purpose of the conformity of the certified CO_2 emissions and fuel consumption related properties testing the approval authority shall identify together with the manufacturer the transmission type(s) to be tested. The approval authority shall ensure that the selected transmission type(s) is manufactured to the same standards as for serial production..

7.10 If the result of a test performed in accordance with point 8 is higher than the one specified in point 8.1.3., 3 additional transmissions from the same family shall be tested. If at least one of them fails, provisions of Article 23 shall apply.

8. Production conformity testing

For conformity of the certified CO_2 emissions and fuel consumption related properties testing the following method shall apply upon prior agreement between an approval authority and the applicant for a certificate:

8.1 Conformity testing of transmissions

8.1.1 The transmission efficiency shall be determined following the simplified procedure described in this paragraph.

8.1.2.1 All boundary conditions as specified in this Annex for the certification testing shall apply.

If other boundary conditions for oil type, oil temperature and inclination angle are used, the manufacturer shall clearly show the influence of these conditions and those used for certification regarding efficiency.

8.1.2.2 For the measurement the same testing option shall be used as for the certification testing, limited to the operating points specified in this paragraph.

▼M3

8.1.2.2.1. In the case Option 1 was used for certification testing, the torque independent losses for the two speeds defined in point 3 of 8.1.2.2.2. shall be measured and used for the calculation of the torque losses at the three torque points defined in point 2 in 8.1.2.2.2.

In the case Option 2 was used for certification testing, the torque independent losses for the two speeds defined in point 3 of 8.1.2.2.2. shall be measured. The torque dependent losses at maximum torque shall be measured at the same two speeds. The torque losses at the three torque points defined in point 2 in 8.1.2.2.2. shall be interpolated as described by the certification procedure.

In the case Option 3 was used for certification testing, the torque losses for the 18 operating points defined in 8.1.2.2.2. shall be measured.

▼B

8.1.2.2.2. The efficiency of the transmission shall be determined for 18 operating points defined by the following requirements:

▼B

(1) Gears to use:

The 3 highest gears of the transmission shall be used for testing.

▼M3

(2) Torque range:

In the case Option 1 or 2 was used for certification testing, the following 3 torque points shall be used: 0,6 × max($T_{in,rep}$(inputspeed, gear)), 0,8 × max($T_{in,rep}$(inputspeed, gear)) and max($T_{in,rep}$(inputspeed, gear)) where max($T_{in,rep}$(inputspeed, gear)) is the largest input torque value reported for certification for the combination of input speed and gear in question.

In the case Option 3 was used for certification testing, the 3 highest torque points that were measured at the certification testing for the combination of input speed and gear in question shall be used.

▼B

(3) Speed range:

The two transmission input speeds of 1 200 rpm and 1 600 rpm shall be tested.

▼M3

8.1.2.3 For each of the 18 operating points, the efficiency of the transmission shall be calculated with:

$$\eta_i = \frac{T_{in,set} - T_{loss,rep}}{T_{in,set}}$$

where:

η_i	=	Efficiency of each operation point 1 to 18
$T_{in,set}$	=	Input torque set point value [Nm]
$T_{loss,rep}$	=	Reported torque loss (after uncertainty correction) [Nm]

▼B

8.1.2.4 The total efficiency during conformity of the certified CO_2 emissions and fuel consumption related properties testing $\eta_{A,CoP}$ shall be calculated by the arithmetic mean value of the efficiency of all 18 operating points.

$$\eta_{A,CoP} = \frac{\eta_1 + \eta_2 + [\ldots] + \eta_{18}}{18}$$

▼**B**

8.1.3 The conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when the following condition applies:

The efficiency of the tested transmission during conformity of the certified CO_2 emissions and fuel consumption related properties test $\eta_{A,CoP}$ shall not be lower than X % of the type approved transmission efficiency $\eta_{A,TA}$.

$$\eta_{A,TA} - \eta_{A,CoP} \leq \boldsymbol{X}$$

▼**M1**

X shall be replaced by 1,5 % for SMT/AMT/DCT transmissions and 3 % for APT transmissions or transmission with more than 2 friction shift clutches.

▼**M3**

The efficiency of the approved transmission $\eta_{A,TA}$ shall be calculated by the arithmetic mean value of the efficiency of 18 operating points during certification based on the formulas in 8.1.2.3 and 8.1.2.4, defined by the requirements in 8.1.2.2.2.

▼B

Appendix 1

MODEL OF A CERTIFICATE OF A COMPONENT, SEPARATE TECHNICAL UNIT OR SYSTEM

Maximum format: A4 (210 × 297 mm)

CERTIFICATE ON CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF A TRANSMISSON / TORQUE CONVERTER / OTHER TORQUE TRANSFERRING COMPONENT/ ADDITIONAL DRIVELINE COMPONENT (1) FAMILY

Administration stamp

Communication concerning:

— granting (1)

— extension (1)

— refusal (1)

— withdrawal (1)

of a certificate with regard to Regulation (EC) No 595/2009 as implemented by Regulation (EU) 2017/2400.

Regulation (EC) No XXXXX and Regulation (EU) 2017/2400 as last amended by ....

certification number:

Hash:

Reason for extension:

SECTION I

0.1 Make (trade name of manufacturer):

0.2 Type:

0.3 Means of identification of type, if marked on the component

0.3.1 Location of the marking:

0.4 Name and address of manufacturer:

0.5 In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.6 Name(s) and address(es) of assembly plant(s):

0.7 Name and address of the manufacturer's representative (if any)

SECTION II

1. Additional information (where applicable): see Addendum

1.1. Option used for the determination of the torque losses

1.1.1 In case of transmission: specify for both output torque ranges 0-10 kNm and > 10 kNm separately for each transmission gear

2. Approval authority responsible for carrying out the tests:

(1) Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable)

▼B

3. Date of test report

4. Number of test report

5. Remarks (if any): see Addendum

6. Place

7. Date

8. Signature

Attachments:

1. Information document

2. Test report

▼B

Appendix 2

Transmission information document

Information document no.: Issue:

Date of issue:

Date of Amendment:

pursuant to …

▼M1

Transmission type/family (if applicable):

▼B

…

▼B

0. GENERAL

0.1. Name and address of manufacturer

0.2. Make (trade name of manufacturer):

0.3. Transmission type:

0.4. Transmission family:

0.5. Transmission type as separate technical unit/Transmission family as separate technical unit

0.6. Commercial name(s) (if available):

0.7. Means of identification of model, if marked on the transmission:

0.8. In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9. Name(s) and address(es) of assembly plant(s):

0.10. Name and address of the manufacturer's representative:

▼B

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) TRANSMISSION AND THE TRANSMISSION TYPES WITHIN A TRANSMISSION FAMILY

		Parent transmission or transmission type	Family members		
			#1	#2	#3

▼M1

___

▼B

1.0	SPECIFIC TRANSMISSION/TRANSMISSION FAMILY INFORMATION				
1.1	Gear ratio. Gearscheme and powerflow				
1.2	Center distance for countershaft transmissions				
1.3	Type of bearings at corresponding positions (if fitted)				
1.4	Type of shift elements (tooth clutches, including synchronisers or friction clutches) at corresponding positions (where fitted)				
1.5	Single gear width for Option 1 or Single gear width ± 1 mm for Option 2 or Option 3				
1.6	Total number of forward gears				
1.7	Number of tooth shift clutches				
1.8	Number of synchronizers				
1.9	Number of friction clutch plates (except for single dry clutch with 1 or 2 plates)				
1.10	Outer diameter of friction clutch plates (except for single dry clutch with 1 or 2 plates)				
1.11	Surface roughness of the teeth (incl. drawings)				
1.12	Number of dynamic shaft seals				
1.13	Oil flow for lubrication and cooling per transmission input shaft revolution				
1.14	Oil viscosity at 100 °C (± 10 %)				
1.15	System pressure for hydraulically controlled gearboxes				
1.16	Specified oil level in reference to central axis and in accordance with the drawing specification (based on average value between lower and upper tolerance) in static or running condition. The oil level is considered as equal if all rotating transmission parts (except for the oil pump and the drive thereof) are located above the specified oil level				

▼B

1.17 Specified oil level (± 1 mm)

1.18 ►M3 Gear ratios [-] and maximum input torque [Nm], maximum input power (kW) and maximum input speed [rpm] for the highest rated version per family member (where the same family member is sold with different commercial names) ◄

1 gear

2 gear

3 gear

4 gear

5 gear

6 gear

7 gear

8 gear

9 gear

10 gear

11 gear

12 gear

n gear

▼M3

1.19 TC lock-up clutch slip in fixed gears (yes/no)

If yes, declaration of permanent slip in TC lock-up clutch or input side clutch in separate maps for each gear depending of measured input speed/ torque points, see example of data for gear 1 below:

TC-slip [rpm] Gear 1

Input Torque Reference (Nm)	Input Speed Reference (rpm)					
	600	900	1 200	1 600	2 000	2 500
0	20	50	60	60	60	60
200	30	40	10	10	10	10
400	30	40	20	20	20	20
600	30	40	20	20	20	20
900	30	40	20	20	20	20
1 200	30	40	20	20	20	20

▼B

LIST OF ATTACHMENTS

No.:	Description:	Date of issue:
1	Information on Transmission test conditions	…
2	…	

▼B

Attachment 1 to Transmission information document

Information on test conditions (if applicable)

1.1	Measurement with retarder	yes/no
1.2	Measurement with angle drive	yes/no
1.3	Maximum tested input speed [rpm]	
1.4	Maximum tested input torque [Nm]	

▼B

Appendix 3

Hydrodynamic torque converter (TC) information document

Information document no.: Issue:

Date of issue:

Date of Amendment:

pursuant to …

▼M1

TC type/family (if applicable):

▼B

…

▼B

0. GENERAL

0.1 Name and address of manufacturer

0.2 Make (trade name of manufacturer):

0.3 TC type:

0.4 TC family:

0.5 TC type as separate technical unit / TC family as separate technical unit

0.6 Commercial name(s) (if available):

0.7 Means of identification of model, if marked on the TC:

0.8 In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9 Name(s) and address(es) of assembly plant(s):

0.10 Name and address of the manufacturer's representative:

▼B

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) TC AND THE TC TYPES WITHIN A TC FAMILY

	Parent TC or	Family members		
	TC type	#1	#2	#3

▼M1

____

▼B

1.0 SPECIFIC TORQUE CONVERTER/TORQUE CONVERTER FAMILY INFORMATION

1.1 For hydrodynamic torque converter without mechanical transmission (serial arrangement).

1.1.1 Outer torus diameter

1.1.2 Inner torus diameter

1.1.3 Arrangement of pump (P), turbine (T) and stator (S) in flow direction

1.1.4 Torus width

1.1.5 Oil type according to test specification

1.1.6 Blade design

1.2 For hydrodynamic torque converter with mechanical transmission (parallel arrangement).

1.2.1 Outer torus diameter

1.2.2 Inner torus diameter

1.2.3 Arrangement of pump (P), turbine (T) and stator (S) in flow direction

1.2.4 Torus width

1.2.5 Oil type according to test specification

1.2.6 Blade design

1.2.7 Gear scheme and power flow in torque converter mode

1.2.8 Type of bearings at corresponding positions (if fitted)

1.2.9 Type of cooling/lubrication pump (referring to parts list)

1.2.10 Type of shift elements (tooth clutches (including synchronisers) OR friction clutches) at corresponding positions where fitted

1.2.11 Oil level according to drawing in reference to central axis

▼B

LIST OF ATTACHMENTS

No.:	Description:	Date of issue:
1	Information on Torque Converter test conditions	…
2	…	

▼B

Attachment 1 to Torque Converter information document

Information on test conditions (if applicable)

1. Method of measurement

1.1 TC with mechanical transmission yes/no

1.2 TC as separate unit yes/no

▼B

Appendix 4

Other torque transferring components (OTTC) information document

Information document no.: Issue:

Date of issue:

Date of Amendment:

pursuant to …

▼M1

OTTC type/family (if applicable):

▼B

…

▼**B**

0. GENERAL

0.1 Name and address of manufacturer

0.2 Make (trade name of manufacturer):

0.3 OTTC type:

0.4 OTTC family:

0.5 OTTC type as separate technical unit/OTTC family as separate technical unit

0.6 Commercial name(s) (if available):

0.7 Means of identification of model, if marked on the OTTC:

0.8 In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9 Name(s) and address(es) of assembly plant(s):

0.10 Name and address of the manufacturer's representative:

▼B

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) OTTC AND THE OTTC TYPES WITHIN AN OTTC FAMILY

	Parent OTTC	Family member		
		#1	#2	#3

▼M1

____

▼B

1.0 SPECIFIC OTTC INFORMATION

1.1 For hydrodynamic torque transferring components (OTTC) / retarder

1.1.1 Outer torus diameter

1.1.2 Torus width

1.1.3 Blade design

1.1.4 Operating fluid

1.1.5 Outer torus diameter - inner torus diameter (OD-ID)

1.1.6 Number of blades

1.1.7 Operating fluid viscosity

1.2 For magnetic torque transferring components (OTTC) / Retarder

1.2.1 Drum design (electro magnetic retarder or permanent magnetic retarder)

1.2.2 Outer rotor diameter

1.2.3 Cooling blade design

1.2.4 Blade design

1.2.5 Operating fluid

1.2.6 Outer rotor diameter - inner rotor diameter (OD-ID)

1.2.7 Number of rotors

1.2.8 Number of cooling blades/blades

1.2.9 Operating fluid viscosity

1.2.10 Number of arms

1.3 For torque transferring components (OTTC)/hydrodynamic clutch

1.3.1 Outer torus diameter

1.3.2 Torus width

1.3.3 Blade design.

1.3.4 Operating fluid viscosity

1.3.5 Outer torus diameter - inner torus diameter (OD-ID)

1.3.6 Number of blades

▼B

LIST OF ATTACHMENTS

No.:	Description:	Date of issue:
1	Information on OTTC test conditions	…
2	…	

▼B

Attachment 1 to OTTC information document

Information on test conditions (if applicable)

1. Method of measurement

   with transmission yes/no

   with engine yes/no

   drive mechanism yes/no

   direct yes/no

2. Maximum test speed of OTTC main torque absorber e.g. retarder rotor [rpm]

▼B

Appendix 5

Additional driveline components (ADC) information document

Information document no.: Issue:

Date of issue:

Date of Amendment:

pursuant to …

▼M1

ADC type/family (if applicable):

▼B

…

▼**B**

0. GENERAL

0.1 Name and address of manufacturer

0.2 Make (trade name of manufacturer):

0.3 ADC type:

0.4 ADC family:

0.5 ADC type as separate technical unit/ADC family as separate technical unit

0.6 Commercial name(s) (if available):

0.7 Means of identification of model, if marked on the ADC:

0.8 In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9 Name(s) and address(es) of assembly plant(s):

0.10 Name and address of the manufacturer's representative:

▼B

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) ADC AND THE ADC TYPES WITHIN AN ADC FAMILY

	Parent-ADC	Family member		
		#1	#2	#3

▼M1

———

▼B

1.0 SPECIFIC ADC/ANGLE DRIVE INFORMATION

1.1 Gear ratio and gearscheme

1.2 Angle between input/output shaft

1.3 Type of bearings at corresponding positions

1.4 Number of teeth per gearwheel

1.5 Single gear width

1.6 Number of dynamic shaft seals

1.7 Oil viscosity (± 10 %)

1.8 Surface roughness of the teeth

1.9 Specified oil level in reference to central axis and in accordance with the drawing specification (based on average value between lower and upper tolerance) in static or running condition. The oil level is considered as equal if all rotating transmission parts (except for the oil pump and the drive thereof) are located above the specified oil level

1.10 Oil level within (± 1mm).

▼B

LIST OF ATTACHMENTS

No.:	Description:	Date of issue:
1	Information on ADC test conditions	…
2	…	

▼B

Attachment 1 to ADC information document

Information on test conditions (if applicable)

1. Method of measurement

with transmission	yes/no
drive mechanism	yes/no
direct	yes/no

2. Maximum test speed at ADC input [rpm]

▼B

Appendix 6

Family Concept

1. General

A transmission, torque converter, other torque transferring components or additional driveline components family is characterized by design and performance parameters. These shall be common to all members within the family. The manufacturer may decide which transmission, torque converter, other torque transferring components or additional driveline components belong to a family, as long as the membership criteria listed in this Appendix are respected. The related family shall be approved by the Approval Authority. The manufacturer shall provide to the Approval Authority the appropriate information relating to the members of the family.

1.1 Special cases

In some cases there may be interaction between parameters. This shall be taken into consideration to ensure that only transmissions, torque converter, other torque transferring components or additional driveline components with similar characteristics are included within the same family. These cases shall be identified by the manufacturer and notified to the Approval Authority. It shall then be taken into account as a criterion for creating a new transmission, torque converter, other torque transferring components or additional driveline components family.

In case of devices or features, which are not listed in paragraph 9. and which have a strong influence on the level of performance, this equipment shall be identified by the manufacturer on the basis of good engineering practice, and shall be notified to the Approval Authority. It shall then be taken into account as a criterion for creating a new transmission, torque converter, other torque transferring components or additional driveline components family.

1.2 The family concept defines criteria and parameters enabling the manufacturer to group transmission, torque converter, other torque transferring components or additional driveline components into families and types with similar or equal CO_2-relevant data.

2. The Approval Authority may conclude that the highest torque loss of the transmission, torque converter, other torque transferring components or additional driveline components family can best be characterized by additional testing. In this case, the manufacturer shall submit the appropriate information to determine the transmission, torque converter, other torque transferring components or additional driveline components within the family likely to have the highest torque loss level.

If members within a family incorporate other features which may be considered to affect the torque losses, these features shall also be identified and taken into account in the selection of the parent.

3. Parameters defining the transmission family

3.1 The following criteria shall be the same to all members within a transmission family.

(a) Gear ratio, gearscheme and powerflow (for forward gears only, crawler gears excluded);

▼B

(b) Center distance for countershaft transmissions;

(c) Type of bearings at corresponding positions (if fitted);

(d) Type of shift elements (tooth clutches, including synchronisers or friction clutches) at corresponding positions (where fitted).

3.2 The following criteria shall be common to all members within a transmission family. The application of a specific range to the parameters listed below is permitted after approval of the Approval Authority

(a) Single gear width ± 1 mm;

(b) Total number of forward gears;

(c) Number of tooth shift clutches;

(d) Number of synchronizers;

(e) Number of friction clutch plates (except for single dry clutch with 1 or 2 plates);

(f) Outer diameter of friction clutch plates (except for single dry clutch with 1 or 2 plates);

(g) Surface roughness of the teeth;

(h) Number of dynamic shaft seals;

(i) Oil flow for lubrication and cooling per input shaft revolution;

(j) Oil viscosity (± 10 %);

(k) System pressure for hydraulically controlled gearboxes;

(l) Specified oil level in reference to central axis and in accordance with the drawing specification (based on average value between lower and upper tolerance) in static or running condition. The oil level is considered as equal if all rotating transmission parts (except for the oil pump and the drive thereof) are located above the specified oil level;

(m) Specified oil level (± 1mm).

4. Choice of the parent transmission

The parent transmission shall be selected using the following criteria listed below.

(a) Highest single gear width for Option 1 or highest Single gear width ± 1 mm for Option 2 or Option 3;

(b) Highest total number of gears;

(c) Highest number of tooth shift clutches;

(d) Highest number of synchronizers;

(e) Highest number of friction clutch plates (except for single dry clutch with 1 or 2 plates);

(f) Highest value of the outer diameter of friction clutch plates (except for single dry clutch with 1 or 2 plates);

▼B

(g) Highest value for the surface roughness of the teeth;

(h) Highest number of dynamic shaft seals;

(i) Highest oil flow for lubrication and cooling per input shaft revolution;

(j) Highest oil viscosity;

(k) Highest system pressure for hydraulically controlled gearboxes;

(l) Highest specified oil level in reference to central axis and in accordance with the drawing specification (based on average value between lower and upper tolerance) in static or running condition. The oil level is considered as equal if all rotating transmission parts (except for the oil pump and the drive thereof) are located above the specified oil level;

(m) Highest specified oil level (± 1 mm).

5. Parameters defining the torque converter family

5.1 The following criteria shall be the same to all members within a torque converter (TC) family.

5.1.1 For hydrodynamic torque converter without mechanical transmission (serial arrangement).

(a) Outer torus diameter;

(b) Inner torus diameter;

(c) Arrangement of pump (P), turbine (T) and stator (S) in flow direction;

(d) Torus width;

(e) Oil type according to test specification;

(f) Blade design;

5.1.2 For hydrodynamic torque converter with mechanical transmission (parallel arrangement).

(a) Outer torus diameter;

(b) Inner torus diameter;

(c) Arrangement of pump (P), turbine (T) and stator (S) in flow direction;

(d) Torus width;

(e) Oil type according to test specification;

(f) Blade design

(g) Gear scheme and power flow in torque converter mode

(h) Type of bearings at corresponding positions (if fitted)

(i) Type of cooling/lubrication pump (referring to parts list)

(j) Type of shift elements (tooth clutches (including synchronisers) or friction clutches) at corresponding positions where fitted

▼B

5.1.3 The following criteria shall be common to all members within a hydrodynamic torque converter with mechanical transmission (parallel arrangement) family. The application of a specific range to the parameters listed below is permitted after approval of the Approval Authority

(a) Oil level according to drawing in reference to central axis.

6. Choice of the parent torque converter

6.1 For hydrodynamic torque converter without mechanical (serial arrangement) transmission.

As long as all criteria listed in 5.1.1 are identical every member of the torque converter without mechanical transmission family can be selected as parent.

6.2 For hydrodynamic torque converter with mechanical transmission.

The parent hydrodynamic torque converter with mechanical transmission (parallel arrangement) shall be selected using the following criteria listed below.

(a) Highest oil level according to drawing in reference to central axis.

7. Parameters defining the other torque transferring components (OTTC) family

7.1 The following criteria shall be the same to all members within a hydrodynamic torque transferring components / retarder family.

(a) Outer torus diameter;

(b) Torus width;

(c) Blade design;

(d) Operating fluid.

7.2 The following criteria shall be the same to all members within a magnetic torque transferring components/retarder family.

(a) Drum design (electro magnetic retarder or permanent magnetic retarder);

(b) Outer rotor diameter;

(c) Cooling blade design;

(d) Blade design.

7.3 The following criteria shall be the same to all members within a torque transferring components / hydrodynamic clutch family.

(a) Outer torus diameter;

(b) Torus width;

(c) Blade design.

▼B

7.4 The following criteria shall be common to all members within a hydrodynamic torque transferring components/retarder family. The application of a specific range to the parameters listed below is permitted after approval of the Approval Authority.

(a) Outer torus diameter - inner torus diameter (OD-ID);

(b) Number of blades;

(c) Operating fluid viscosity (± 50 %).

7.5 The following criteria shall be common to all members within a magnetic torque transferring components / retarder family. The application of a specific range to the parameters listed below is permitted after approval of the Approval Authority.

(a) Outer rotor diameter - inner rotor diameter (OD-ID);

(b) Number of rotors;

(c) Number of cooling blades / blades;

(d) Number of arms.

7.6 The following criteria shall be common to all members within a torque transferring components / hydrodynamic clutch family. The application of a specific range to the parameters listed below is permitted after approval of the Approval Authority.

(a) Operating fluid viscosity (± 10 %);

(b) Outer torus diameter - inner torus diameter (OD-ID);

(c) Number of blades.

8. Choice of the parent torque transferring component

8.1 The parent hydrodynamic torque transferring component/retarder shall be selected using the following criteria listed below.

(a) Highest value: outer torus diameter – inner torus diameter (OD-ID);

(b) Highest number of blades;

(c) Highest operating fluid viscosity.

8.2 The parent magnetic torque transferring component / retarder shall be selected using the following criteria listed below.

(a) Highest outer rotor diameter – highest inner rotor diameter (OD-ID);

(b) Highest number of rotors;

(c) Highest number of cooling blades/blades;

(d) Highest number of arms.

▼B

8.3 The parent torque transferring component/hydrodynamic clutch shall be selected using the following criteria listed below.

(a) Highest operating fluid viscosity (± 10 %);

(b) Highest outer torus diameter – highest inner torus diameter (OD-ID);

(c) Highest number of blades.

9. Parameters defining the additional driveline components family

9.1 The following criteria shall be the same to all members within an additional driveline components/angle drive family family.

(a) Gear ratio and gearscheme;

(b) Angle between input/output shaft;

(c) Type of bearings at corresponding positions

9.2 The following criteria shall be common to all members within an additional driveline components/angle family. The application of a specific range to the parameters listed below is permitted after approval of the Approval Authority.

(a) Single gear width;

(b) Number of dynamic shaft seals;

(c) Oil viscosity (± 10 %);

(d) Surface roughness of the teeth;

(e) Specified oil level in reference to central axis and in accordance with the drawing specification (based on average value between lower and upper tolerance) in static or running condition. The oil level is considered as equal if all rotating transmission parts (except for the oil pump and the drive thereof) are located above the specified oil level.

10. Choice of the parent additional driveline component

10.1 The parent additional driveline component / angle drive shall be selected using the following criteria listed below.

(a) Highest single gear width;

(a) Highest number of dynamic shaft seals;

(c) Highest oil viscosity (± 10 %);

(d) Highest surface roughness of the teeth;

(e) Highest specified oil level in reference to central axis and in accordance with the drawing specification (based on average value between lower and upper tolerance) in static or running condition. The oil level is considered as equal if all rotating transmission parts (except for the oil pump and the drive thereof) are located above the specified oil level.

▼B

Appendix 7

Markings and numbering

1. Markings

In the case of a component being certified in accordance with this Annex, the component shall bear:

▼M1

1.1. The manufacturer's name or trade mark

1.2. The make and identifying type indication as recorded in the information referred to in point 0.2 and 0.3 of Appendices 2 - 5 to this Annex

▼B

1.3 The certification mark (if applicable) as a rectangle surrounding the lower-case letter ‘e’ followed by the distinguishing number of the Member State which has granted the certificate:

1 for Germany;

2 for France;

3 for Italy;

4 for the Netherlands;

5 for Sweden;

6 for Belgium;

7 for Hungary;

8 for the Czech Republic;

9 for Spain;

11 for the United Kingdom;

12 for Austria;

13 for Luxembourg;

17 for Finland;

18 for Denmark;

19 for Romania;

20 for Poland;

21 for Portugal;

23 for Greece;

24 for Ireland;

25 for Croatia;

26 for Slovenia;

27 for Slovakia;

29 for Estonia;

32 for Latvia;

34 for Bulgaria;

36 for Lithuania;

49 for Cyprus;

50 for Malta

1.4 ►M3 The certification mark shall also include in the vicinity of the rectangle the ‘base approval number’ as specified for Section 4 of the type-approval number set out in Annex IV to Regulation (EU) 2020/683, preceded by the two figures indicating the sequence number assigned to the latest technical amendment to this Regulation and by an alphabetical character indicating the part for which the certificate has been granted. ◄

For this Regulation, the sequence number shall be ►M3 02 ◄.

For this Regulation, the alphabetical character shall be the one laid down in Table 1.

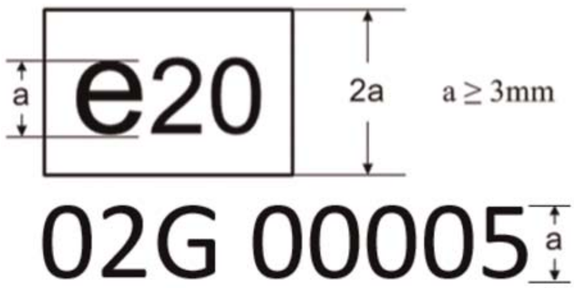
▼B

Table 1

▼M1 G	Transmission
▼B C	Torque Converter (TC)
O	Other torque transferring component (OTTC)
D	Additional driveline component (ADC)

▼M3

1.5 Example of the certification mark



The above certification mark affixed to a transmission, torque converter (TC), other torque transferring component (OTTC) or additional drivetrain component (ADC) shows that the type concerned has been certified in Poland (e20), pursuant to this Regulation. The first two digits (02) are indicating the sequence number assigned to the latest technical amendment to this Regulation. The following digit indicates that the certification was granted for a transmission (G). The last five digits (00005) are those allocated by the approval authority to the transmission, as the base approval number.

▼B

1.6 On request of the applicant for certificate and after prior agreement with the approval authority other type sizes than indicated in 1.5 may be used. Those other type sizes shall remain clearly legible.

1.7 The markings, labels, plates or stickers must be durable for the useful life of the transmission, torque converter (TC), other torque transferring components (OTTC) or additional driveline components (ADC) and must be clearly legible and indelible. The manufacturer shall ensure that the markings, labels, plates or sticker cannot be removed without destroying or defacing them.

1.8 In the case separate certifications are granted by the same approval authority for a transmission, a torque converter, other torque transferring components or additional driveline components and those parts are installed in combination, the indication of one certification mark referred to in point 1.3 is sufficient. This certification mark shall be followed by the applicable markings specified in point 1.4 for the respective transmission, torque converter, other torque transferring component or additional driveline component separated by '/'.

▼B

1.9. The certification mark shall be visible when the transmission, torque converter, other torque transferring component or additional driveline component is installed on the vehicle and shall be affixed to a part necessary for normal operation and not normally requiring replacement during component life.

1.10 In the case that torque converter or other torque transferring components are constructed in such a way that they are not accessible and / or visible after being assembled with a transmission the certification mark of the torque converter or other torque transferring component shall be placed on the transmission.

In the case described in first paragraph, if a torque converter or other torque transferring component have not been certified, '–' instead of the certification number shall be indicated on the transmission next to the alphabetical character specified in point 1.4.

2. Numbering

▼M3

2.1 Certification number for transmissions, torque converter, other torque transferring component and additional drivetrain component shall comprise the following:

eX*YYYY/YYYY*ZZZZ/ZZZZ*X*00000*00

section 1	section 2	section 3	Additional letter to section 3	section 4	section 5
Indication of country issuing the certificate	HDV CO_2 determination Regulation '2017/2400'	Latest amending Regulation (ZZZZ/ZZZZ)	See Table 1 of this Appendix	Base certification number 00000	Extension 00

▼B

Appendix 8

Standard torque loss values - Transmission

Calculated fallback values based on the maximum rated torque of the transmission:

The torque loss $T_{l,in}$ related to the input shaft of the transmission shall be calculated by

$$T_{l,in} = (T_{d0} + T_{add0}) + (T_{d1000} + T_{add1000}) \times \frac{n_{in}}{1\,000\ rpm} + (f_T + f_{T\_add}) \times T_{in}$$

where:

$T_{l,in}$ = Torque loss related to the input shaft [Nm]

T_{dx} = Drag torque at x rpm [Nm]

T_{addx} = Additional angle drive gear drag torque at x rpm [Nm]

(if applicable)

n_{in} = Speed at the input shaft [rpm]

f_T = 1-η

η = efficiency

f_T = 0,01 for direct gear, 0,04 for indirect gears

f_{T_add} = 0,04 for angle drive gear (if applicable)

T_{in} = Torque at the input shaft [Nm]

For transmissions with tooth shift clutches (Synchronised Manual Transmissions (SMT), Automated Manual Transmissions or Automatic Mechanically engaged Transmissions (AMT) and Dual Clutch Transmissions (DCT)) the drag torque T_{dx} is calculated by

$$T_{dx} = T_{d0} = T_{d1000} = 10\ Nm \times \frac{T_{\max\ in}}{2\,000\ Nm} = 0{,}005 \times T_{\max\ in}$$

where:

$T_{max,in}$ = Maximum allowed input torque in any forward gear of transmission [Nm]

= max($T_{max,in,gear}$)

$T_{max,in,gear}$ = Maximum allowed input torque in gear, where gear = 1, 2, 3,… top gear). For transmissions with hydrodynamic torque converter this input torque shall be the torque at transmission input before torque converter.

▼B

For transmissions with friction shift clutches (> 2 friction clutches) the drag torque T_{dx} is calculated by

$$T_{dx} = T_{d0} = T_{d1000} = 30 \ Nm \times \frac{T_{\max\ in}}{2\ 000\ Nm} = 0{,}015 \times T_{\max\ in}$$

Here, 'friction clutch' is used in the context of a clutch or brake that operates with friction, and is required for sustained torque transfer in at least one gear.

For transmissions including an angle drive (e.g. bevel gear), the additional angle drive drag torque T_{addx} shall be included in the calculation of T_{dx}:

$$T_{addx} = T_{add0} = T_{add1000} = 10\ Nm \times \frac{T_{\max\ in}}{2\ 000\ Nm} = 0{,}005 \times T_{\max\ in}$$

(only if applicable)

▼M3

For transmissions with integrated differential, the integrated differential shall be treated as an angle drive. Thereby, the expressions for T_{add0}, $T_{add1000}$ and $f_{T_{add}}$ above shall be used for calculating $T_{l,in}$.

▼B

Appendix 9

Generic model – torque converter

Generic torque converter model based on standard technology:

For the determination of the torque converter characteristics a generic torque converter model depending on specific engine characteristics may be applied.

The generic TC model is based on the following characteristic engine data:

n_{rated} = Maximum engine speed at maximum power (determined from the engine full-load curve as calculated by the engine pre-processing tool) [rpm]

T_{max} = Maximum engine torque (determined from the engine full-load curve as calculated by the engine pre-processing tool) [Nm]

Thereby the generic TC characteristics are valid only for a combination of the TC with an engine sharing the same specific characteristic engine data.

Description of the four-point model for the torque capacity of the TC:

Generic torque capacity and generic torque ratio:

Figure 1

Generic torque capacity

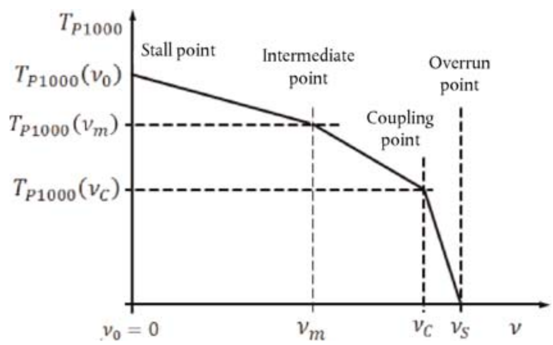
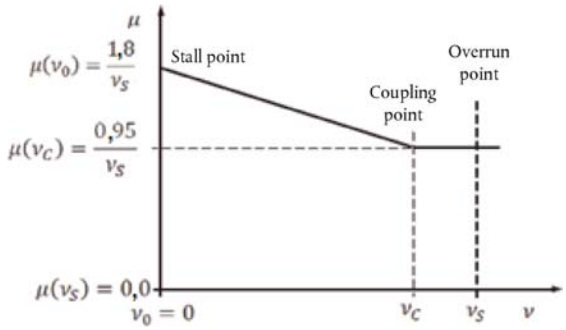


Figure 2

Generic torque ratio



▼B

where:

T_{P1000} = Pump reference torque; $T_{P1000} = T_P \times \left(\frac{1\,000\ rpm}{n_p}\right)^2$ [Nm]

v = Speed ratio; $v = \frac{n_2}{n_1}$ [-]

μ = Torque ratio; $\mu = \frac{T_2}{T_1}$ [-]

v_s = Speed ratio at overrun point; $v_s = \frac{n_2}{n_1}$ [-]

For TC with rotating housing (Trilock-Type) v_s typically is 1. For other TC concepts, especially power split concepts, v_s may have values different from 1.

v_c = Speed ratio at coupling point; $v_c = \frac{n_2}{n_1}$ [-]

v_0 = Stall point; v_0 = 0 [rpm]

v_m = Intermediate speed ratio; $v_m = \frac{n_2}{n_1}$ [-]

The model requires the following definitions for the calculation of the generic torque capacity:

Stall point:

— Stall point at 70 % nominal engine speed.

— Engine torque in stall point at 80 % maximum engine torque.

— Engine/Pump reference torque in stall point:

$$T_{P1000}(v_0) = T_{max} \times 0{,}80 \times \left(\frac{1\,000\ rpm}{0{,}70 \times n_n}\right)^2$$

Intermediate point:

— Intermediate speed ratio v_m = 0,6 * v_s

— Engine/pump reference torque in intermediate point at 80 % of reference torque in stall point:

$$T_{P1000}(v_m) = 0{,}8 \times T_{P1000}(v_0)$$

Coupling point:

— Coupling point at 90 % overrun conditions: v_c = 0,90 * v_s

— Engine/pump reference torque in clutch point at 50 % of reference torque in stall point:

$$T_{P1000}(v_c) = 0{,}5 \times T_{P1000}(v_0)$$

Overrun point:

— Reference torque at overrun conditions = v_s:

$$T_{P1000}(v_s) = 0$$

▼B

The model requires the following definitions for the calculation of the generic torque ratio:

Stall point:

— Torque ratio at stall point $v_0 = v_s = 0$:

$$\mu(v_0) = \frac{1,8}{v_s}$$

Intermediate point:

— Linear interpolation between stall point and coupling point

Coupling point:

— Torque ratio at coupling point $v_c = 0,9 * v_s$:

$$\mu(v_c) = \frac{0,95}{v_s}$$

Overrun point:

— Torque ratio at overrun conditions = v_s:

$$\mu(v_s) = \frac{0,95}{v_s}$$

Efficiency:

$$n = \mu * v$$

Linear interpolation between the calculated specific points shall be used.

▼M3

Appendix 10

Standard torque loss values – other torque transferring components

Calculated standard torque loss values for other torque transferring components:

For primary hydrodynamic retarders (oil or water) with included vehicle launch functionality, the retarder drag torque shall be calculated by

$$T_{retarder} = \frac{20}{i_{step-up}} + \left(\frac{4}{(i_{step-up})^3}\right) \times \left(\frac{n_{retarder}}{1000}\right)^2$$

For other hydrodynamic retarders (oil or water), the retarder drag torque shall be calculated by

$$T_{retarder} = \frac{10}{i_{step-up}} + \left(\frac{2}{(i_{step-up})^3}\right) \times \left(\frac{n_{retarder}}{1000}\right)^2$$

For magnetic retarders (permanent or electro-magnetic), the retarder drag torque shall be calculated by:

$$T_{retarder} = \frac{12}{i_{step-up}} + \left(\frac{5}{(i_{step-up})^4}\right) \times \left(\frac{n_{retarder}}{1000}\right)^2$$

where:

$T_{retarder}$ = Retarder drag loss [Nm]

$n_{retarder}$ = Retarder rotor speed [rpm] (see point 5.1 of this Annex)

$i_{step-up}$ = Step-up ratio = retarder rotor speed / drive component speed (see point 5.1 of this Annex)

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Appendix 11

▼M3

Standard torque loss values – geared angle drive or drivetrain component with a single speed ratio

Consistent with the standard torque loss values for the combination of a transmission with a geared angle drive in Appendix 8, the standard torque losses of a geared angle drive or drivetrain component with a single speed ratio without transmission shall be calculated from:

▼B

$$T_{l,ad,in} = T_{add0} + T_{add1000} \times \frac{n_{in}}{1\,000\ rpm} + f_{T\_add} \times T_{in}$$

where:

$T_{l,in}$ = Torque loss related to the input shaft of transmission [Nm]

T_{addx} = Additional angle drive gear drag torque at x rpm [Nm]

(if applicable)

n_{in} = Speed at the input shaft of transmission [rpm]

f_T = 1-η;

η = efficiency

f_{T_add} = 0,04 for angle drive gear

T_{in} = Torque at the input shaft of transmission [Nm]

$T_{max,in}$ = Maximum allowed input torque in any forward gear of transmission [Nm]

= $\max(T_{max,in,gear})$

$T_{max,in,gear}$ = Maximum allowed input torque in gear, where gear = 1, 2, 3,… top gear)

$$T_{addx} = T_{add0} = T_{add1000} = 10\ Nm \times \frac{T_{\max\ in}}{2\,000\ Nm} = 0{,}005 \times T_{\max\ in}$$

The standard torque losses obtained by the calculations above may be added to the torque losses of a transmission obtained by Options 1-3 in order to obtain the torque losses for the combination of the specific transmission with an angle drive.

▼B

Appendix 12

Input parameters for the simulation tool

Introduction

This Appendix describes the list of parameters to be provided by the transmission, torque converter (TC), other torque transferring components (OTTC) and additional driveline components (ADC) manufacturer as input to the simulation tool. The applicable XML schema as well as example data are available at the dedicated electronic distribution platform.

Definitions

(1) 'Parameter ID': Unique identifier as used in 'Simulation tool' for a specific input parameter or set of input data

(2) 'Type': Data type of the parameter

string .... sequence of characters in ISO8859-1 encoding

token .... sequence of characters in ISO8859-1 encoding, no leading/trailing whitespace

date .... date and time in UTC time in the format: YYYY-MM-DD*T*HH:MM:SS*Z* with italic letters denoting *fixed characters* e.g. '2002-05-30*T*09:30:10*Z*'

integer .... value with an integral data type, no leading zeros, e.g. '1800'

double, X .... fractional number with exactly X digits after the decimal sign ('.') and no leading zeros e.g. for 'double, 2': '2345.67'; for 'double, 4': '45.6780'

(3) 'Unit' … physical unit of the parameter

Set of input parameters

▼M1

Table 1

Input parameters 'Transmission/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P205	token	[-]	
Model	P206	token	[-]	
Certification-Number	P207	token	[-]	
Date	P208	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P209	token	[-]	
TransmissionType	P076	string	[-]	►M3 Allowed values ([39]): 'SMT', 'AMT', 'APT-S', 'APT-P', 'APT-N', 'IHPC Type 1' ◄
MainCertification-Method	P254	string	[-]	Allowed values: 'Option 1', 'Option 2', 'Option 3', 'Standard values'
▼M3 DifferentialIn-cluded	P353	boolean	[-]	
AxlegearRatio	P150	double, 3	[-]	Optional, only required in the event 'DifferentialIncluded' is true.

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([1]) DCT shall be declared as transmission type AMT.

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Table 2

Input parameters 'Transmission/Gears' per gear

Parameter name	Parameter ID	Type	Unit	Description/Reference
GearNumber	P199	integer	[-]	
Ratio	P078	double, 3	[-]	►M3 In the case of transmission with included differential, transmission gear ratio shall only be indicated without considering axle gear ratio ◄
MaxTorque	P157	integer	[Nm]	optional
MaxSpeed	P194	integer	[1/min]	optional

Table 3

Input parameters 'Transmission/LossMap' per gear and for each grid point in the loss map

Parameter name	Parameter ID	Type	Unit	Description/Reference
InputSpeed	P096	double, 2	[1/min]	
InputTorque	P097	double, 2	[Nm]	
TorqueLoss	P098	double, 2	[Nm]	

Table 4

Input parameters 'TorqueConverter/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P210	token	[-]	
Model	P211	token	[-]	
▼M1 Certification-Number	P212	token	[-]	
▼B Date	P213	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P214	string	[-]	
Certification-Method	P257	string	[-]	Allowed values: 'Measured', 'Standard values'

▼B

Table 5

Input parameters 'TorqueConverter/Characteristics' for each grid point in the characteristic curve

Parameter name	Parameter ID	Type	Unit	Description/Reference
SpeedRatio	P099	double, 4	[-]	
TorqueRatio	P100	double, 4	[-]	
InputTorqueRef	P101	double, 2	[Nm]	

Table 6

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Input parameters 'ADC/General' (only required if component applicable)

▼B

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P220	token	[-]	
Model	P221	token	[-]	
▼M1 Certification-Number	P222	token	[-]	
▼B Date	P223	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P224	string	[-]	
Ratio	P176	double, 3	[-]	
Certification-Method	P258	string	[-]	Allowed values: 'Option 1', 'Option 2', 'Option 3', 'Standard values'

Table 7

▼M3

Input parameters 'ADC/LossMap' for each grid point in the loss map (only required if component applicable)

▼B

Parameter name	Parameter ID	Type	Unit	Description/Reference
InputSpeed	P173	double, 2	[1/min]	
InputTorque	P174	double, 2	[Nm]	
TorqueLoss	P175	double, 2	[Nm]	

▼B

Table 8

Input parameters ‘Retarder/General’ (only required if component applicable)

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P225	token	[-]	
Model	P226	token	[-]	
▼M1 Certification-Number	P227	token	[-]	
▼B Date	P228	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P229	string	[-]	
Certification-Method	P255	string	[-]	Allowed values: ‘Measured’, ‘Standard values’

Table 9

Input parameters ‘Retarder/LossMap’ for each grid point in the characteristic curve (only required if component applicable)

Parameter name	Parameter ID	Type	Unit	Description/Reference
RetarderSpeed	P057	double, 2	[1/min]	
TorqueLoss	P058	double, 2	[Nm]	

▼B

ANNEX VII

VERIFYING AXLE DATA

1. Introduction

This Annex describes the certification provisions regarding the torque losses of propulsion axles for heavy duty vehicles. Alternatively to the certification of axles the calculation procedure for the standard torque loss as defined in Appendix 3 to this Annex can be applied for the purpose of the determination of vehicle specific CO_2 emissions.

2. Definitions

For the purposes of this Annex the following definitions shall apply:

(1) 'Single reduction axle (SR)' means a driven axle with only one gear reduction, typically a bevel gear set with or without hypoid offset.

(2) 'Single portal axle (SP)' means an axle, that has typically a vertical offset between the rotating axis of the crown gear and the rotating axis of the wheel due to the demand of a higher ground clearance or a lowered floor to allow a low floor concept for inner city buses. ►M3 Typically, the first reduction is a bevel gear set, the second one a spur gear set (or helical gear set) with vertical offset close to the wheels. ◄

(3) 'Hub reduction axle (HR)' means a driven axle with two gear reductions. The first is typically a bevel gear set with or without hypoid offset. The other is a planetary gear set, what is typically placed in the area of the wheel hubs.

(4) 'Single reduction tandem axle (SRT)' means a driven axle that is basically similar to a single driven axle, but has also the purpose to transfer torque from the input flange over an output flange to a further axle. The torque can be transferred with a spur gear set close at the input flange to generate a vertical offset for the output flange. Another possibility is to use a second pinion at the bevel gear set, what takes off torque at the crown wheel.

(5) 'Hub reduction tandem axle (HRT)' means a hub reduction axle, what has the possibility to transfer torque to the rear as described under single reduction tandem axle (SRT).

(6) 'Axle housing' means the housing parts that are needed for structural capability as well as for carrying the driveline parts, bearings and sealings of the axle.

(7) 'Pinion' means a part of a bevel gear set which usually consists of two gears. The pinion is the driving gear which is connected with the input flange. In case of a SRT / HRT, a second pinion can be installed to take off torque from the crown wheel.

(8) 'Crown wheel' means a part of a bevel gear set which usually consists of two gears. The crown wheel is the driven gear and is connected with the differential cage.

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(9) 'Hub reduction' means the planetary gear set that is installed commonly outside the planetary bearing at hub reduction axles. The gear set consists of three different gears. The sun, the planetary gears and the ring gear. The sun is in the centre, the planetary gears are rotating around the sun and are mounted to the planetary carrier that is fixed to the hub. Typically, the number of planetary gears is between three and five. The ring gear is not rotating and fixed to the axle beam.

(10) 'Planetary gear wheels' means the gears that rotate around the sun within the ring gear of a planetary gear set. They are assembled with bearings on a planetary carrier, what is joined to a hub.

(11) 'Oil type viscosity grade' means a viscosity grade as defined by SAE J306.

(12) 'Factory fill oil' means the oil type viscosity grade that is used for the oil fill in the factory and which is intended to stay in the axle for the first service interval.

(13) 'Axle line' means a group of axles that share the same basic axle-function as defined in the family concept.

(14) 'Axle family' means a manufacturer's grouping of axles which through their design, as defined in Appendix 4 of this Annex, have similar design characteristics and CO_2 and fuel consumption properties.

(15) 'Drag torque' means the required torque to overcome the inner friction of an axle when the wheel ends are rotating freely with 0 Nm output torque.

(16) 'Mirror inverted axle casing' means the axle casing is mirrored regarding to the vertical plane.

(17) 'Axle input' means the side of the axle on which the torque is delivered to the axle.

(18) 'Axle output' means the side(s) of the axle where the torque is delivered to the wheels.

3. General requirements

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The axle gears and all bearings shall be new for the verification of axle losses, while wheel end bearings may already be run in and may be used for multiple measurements.

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On request of the applicant different gear ratios can be tested in one axle housing using the same wheel ends.

Different axle ratios of hub reduction axles and single portal axles (HR, HRT, SP) may be measured by exchanging the hub reduction only. The provisions as specified in Appendix 4 to this Annex shall apply.

The total run-time for the optional run-in and the measurement of an individual axle (except for the axle housing and wheel-ends) shall not exceed 120 hours.

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For testing the losses of an axle the torque loss map for each ratio of an individual axle shall be measured, however axles can be grouped in axle families following the provisions of Appendix 4 to this Annex.

3.1 Run-in

On request of the applicant a run-in procedure may be applied to the axle. The following provisions shall apply for a run-in procedure.

3.1.1 Only factory fill oil shall be used for the run-in procedure. The oil used for the run-in shall not be used for the testing described in paragraph 4.

3.1.2 The speed and torque profile for the run-in procedure shall be specified by the manufacturer.

3.1.3 The run-in procedure shall be documented by the manufacturer with regard to run-time, speed, torque and oil temperature and reported to the approval authority.

3.1.4 The requirements for the oil temperature (4.3.1), measurement accuracy (4.4.7) and test set-up (4.2) do not apply for the run-in procedure.

4. Testing procedure for axles

4.1 Test conditions

4.1.1 Ambient temperature

The temperature in the test cell shall be maintained to 25 °C ± 10 °C. The ambient temperature shall be measured within a distance of 1 m to the axle housing. Forced heating of the axle may only be applied by an external oil conditioning system as described in 4.1.5.

4.1.2 Oil temperature

The oil temperature shall be measured at the centre of the oil sump or at any other suitable point in accordance with good engineering practice. In case of external oil conditioning, alternatively the oil temperature can be measured in the outlet line from the axle housing to the conditioning system within 5 cm downstream the outlet. In both cases the oil temperature shall not exceed 70 °C.

4.1.3 Oil quality

Only recommended factory fill oils as specified by the axle manufacturer shall be used for the measurement. ►M3 In the case of testing different gear ratio variants with one axle housing, new oil shall be filled in for each single measurement of the whole axle system. ◄

4.1.4 Oil viscosity

If different oils with multiple viscosity grades are specified for the factory fill, the manufacturer shall choose the oil with the highest viscosity grade for performing the measurements on the parent axle.

If more than one oil within the same viscosity grade is specified within one axle family as factory fill oil, the applicant may choose one oil of these for the measurement related to certification.

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4.1.5 Oil level and conditioning

The oil level or filling volume shall be set to the maximum level as defined in the manufacturer's maintenance specifications.

An external oil conditioning and filtering system is permitted. The axle housing may be modified for the inclusion of the oil conditioning system.

The oil conditioning system shall not be installed in a way which would enable changing oil levels of the axle in order to raise efficiency or to generate propulsion torques in accordance with good engineering practice.

4.2 Test set-up

For the purpose of the torque loss measurement different test set-ups are permitted as described in paragraph 4.2.3 and 4.2.4.

4.2.1 Axle installation

In case of a tandem axle, each axle shall be measured separately. The first axle with longitudinal differential shall be locked. The output shaft of drive-through axles shall be installed freely rotatable.

4.2.2 Installation of torque meters

4.2.2.1 For a test setup with two electric machines, the torque meters shall be installed on the input flange and on one wheel end while the other one is locked.

4.2.2.2 For a test setup with three electric machines, the torque meters shall be installed on the input flange and on each wheel end.

4.2.2.3 Half shafts of different lengths are permitted in a two machine set-up in order to lock the differential and to ensure that both wheel ends are turning.

4.2.3 Test set-up 'Type A'

A test set-up considered 'Type A' consists of a dynamometer on the axle input side and at least one dynamometer on the axle output side(s). Torque measuring devices shall be installed on the axle input- and output- side(s). ►**M3** For type A setups with only one dynamometer on the output side, the freely rotating end of the axle shall be rotatably locked to the other end on the output side (e.g. by an activated differential lock or by means of any other mechanical differential lock implemented only for the measurement). ◄

To avoid parasitic losses, the torque measuring devices shall be positioned as close as possible to the axle input- and output- side(s) being supported by appropriate bearings.

Additionally mechanical isolation of the torque sensors from parasitic loads of the shafts, for example by installation of additional bearings and a flexible coupling or lightweight cardan shaft between the sensors and one of these bearings can be applied. ►**M3** Figure 1 shows an example for a test setup of Type A in a two dynamometer lay-out. ◄

For Type A test set-up configurations the manufacturer shall provide an analysis of the parasitic loads. Based on this analysis the approval authority shall decide about the maximum influence of parasitic loads. However the value i_{para} cannot be lower than 10 %.

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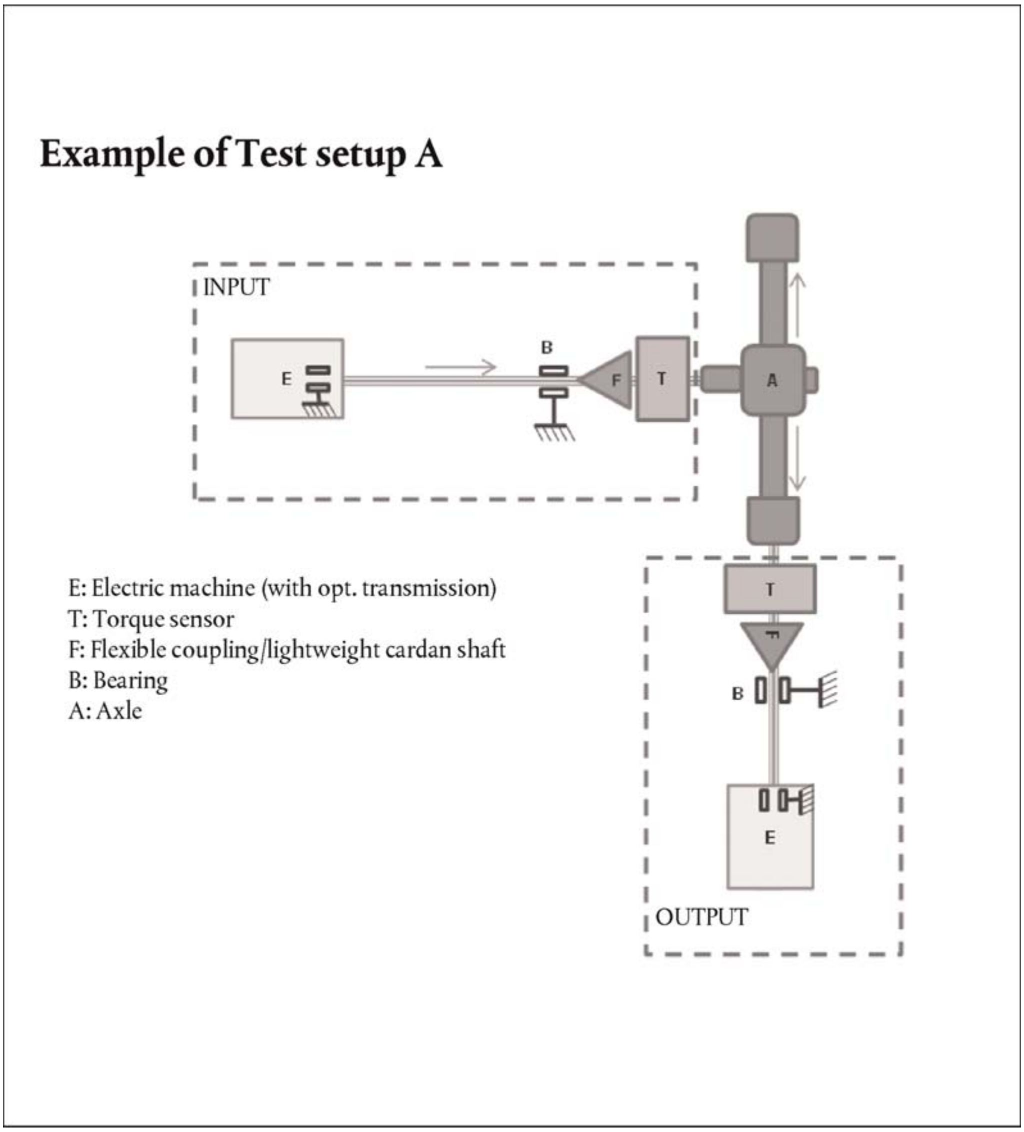
Figure 1

Example of Test set-up 'Type A'



4.2.4 Test set-up 'Type B'

Any other test set-up configuration is called test set-up Type B. The maximum influence of parasitic loads i_{para} for those configurations shall be set to 100 %.

Lower values for i_{para} may be used in agreement with the approval authority.

4.3 Test procedure

To determine the torque loss map for an axle, the basic torque loss map data shall be measured and calculated as specified in paragraph 4.4. ►M1 The torque loss results shall be complemented in accordance with 4.4.8 and formatted in accordance with Appendix 6 for the further processing by the simulation tool. ◄

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4.3.1 Measurement equipment

The calibration laboratory facilities shall comply with the requirements of either ►M3 IATF ◄ 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.

4.3.1.1 Torque measurement

The torque measurement uncertainty shall be calculated and included as described in paragraph 4.4.7.

The sample rate of the torque sensors shall be in accordance with 4.3.2.1.

4.3.1.2 Rotational speed

The uncertainty of the rotational speed sensors for the measurement of input and output speed shall not exceed ± 2 rpm.

4.3.1.3 Temperatures

The uncertainty of the temperature sensors for the measurement of the ambient temperature shall not exceed ± 1 °C.

The uncertainty of the temperature sensors for the measurement of the oil temperature shall not exceed ± 0,5 °C.

4.3.2 Measurement signals and data recording

The following signals shall be recorded for the purpose of the calculation of the torque losses:

(i) Input and output torques [Nm]

(ii) Input and/or output rotational speeds [rpm]

(iii) Ambient temperature [°C]

(iv) Oil temperature [°C]

(v) Temperature at the torque sensor ►M3 [°C] (optional) ◄

4.3.2.1 The following minimum sampling frequencies of the sensors shall be applied:

Torque: 1 kHz

Rotational speed: 200 Hz

Temperatures: 10 Hz

4.3.2.2 The recording rate of the data used to determine the arithmetic mean values of each grid point shall be 10 Hz or higher. The raw data do not need to be reported.

Signal filtering may be applied in agreement with the approval authority. Any aliasing effect shall be avoided.

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4.3.3 Torque range:

The extent of the torque loss map to be measured is limited to:

— either an output torque of 10 kNm for heavy lorries and heavy buses or 2 kNm for medium lorries;

— or an input torque of 5 kNm for heavy lorries and heavy buses or 1 kNm for medium lorries;

▼M3

— or the maximum engine power tolerated by the manufacturer for a specific axle or in the case of multiple driven axles in accordance with the nominal power distribution.

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4.3.3.1 The manufacturer may extend the measurement up to 20 kNm output torque by means of linear extrapolation of torque losses or by performing measurements up to 20 kNm output torque with steps of 2 000 Nm. For this additional torque range another torque sensor at the output side with a maximum torque of 20 kNm (2-machine layout) or two 10 kNm sensors (3-machine layout) shall be used.

If the radius of the smallest tire is reduced (e.g. product development) after completing the measurement of an axle or when the physic boundaries of the test stand are reached (e.g. by product development changes), the missing points may be extrapolated by the manufacturer out of the existing map. The extrapolated points shall not exceed more than 10 % of all points in the map and the penalty for these points is 5 % torque loss to be added on the extrapolated points.

▼M3

4.3.3.2 Output torque steps to be measured for heavy lorries and heavy buses:

250 Nm < T_{out} < 1 000 Nm: 250 Nm steps

1 000 Nm ≤ T_{out} ≤ 2 000 Nm: 500 Nm steps

2 000 Nm ≤ T_{out} ≤ 10 000 Nm: 1 000 Nm steps

T_{out} > 10 000 Nm: 2 000 Nm steps

Output torque steps to be measured for medium lorries:

50 Nm < T_{out} < 200 Nm: 50 Nm steps

200 Nm ≤ T_{out} ≤ 400 Nm: 100 Nm steps

400 Nm ≤ T_{out} ≤ 2 000 Nm: 200 Nm steps

T_{out} > 2 000 Nm: 400 Nm steps

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4.3.4 Speed range

The range of test speeds shall comprise from 50 rpm wheel speed to the maximum speed. The maximum test speed to be measured is defined by either the maximum axle input speed or the maximum wheel speed, whichever of the following conditions is reached first:

4.3.4.1 The maximum applicable axle input speed may be limited to design specification of the axle.

4.3.4.2 ►M3 The maximum wheel speed is measured under consideration of the smallest applicable tire diameter at a vehicle speed of 90 km/h for medium and heavy lorries and 110 km/h for heavy buses. ◄ If the smallest applicable tire diameter is not defined, paragraph 4.3.4.1 shall apply.

▼M3

4.3.5 Wheel speed steps to be measured

The wheel speed step width for testing shall be 50 rpm for heavy lorries and heavy buses and 100 rpm for medium lorries. It is permitted to measure intermediate speed steps.

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4.4 Measurement of torque loss maps for axles

4.4.1 Testing sequence of the torque loss map

►M3 For each speed step the torque loss shall be measured for each output torque step starting from the lowest torque value upward to the maximum and downward to the minimum. ◄ The speed steps can be run in any order. ►M1 The torque measurement sequence shall be performed and recorded twice. ◄

Interruptions of the sequence for cooling or heating purposes are permitted.

▼M3

4.4.2 Measurement duration

The measurement duration for each single grid point shall be a minimum of 5 seconds but no longer than 20 seconds.

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4.4.3 Averaging of grid points

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The recorded values for each grid point within the 5-20 seconds interval in accordance with point 4.4.2 shall be averaged to an arithmetic mean.

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All four averaged intervals of corresponding speed and torque grid points from both sequences measured each upward and downward shall be averaged to an arithmetic mean and result into one torque loss value.

4.4.4 The torque loss (at input side) of the axle shall be calculated by

$$T_{loss} = T_{in} - \sum \frac{T_{out}}{i_{gear}}$$

where:

T_{loss} = Torque loss of the axle at the input side [Nm]

T_{in} = Input torque [Nm]

i_{gear} = Axle gear ratio [-]

T_{out} = Output torque [Nm]

4.4.5 Measurement validation

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4.4.5.1 The averaged speed values per grid point (5-20 s interval) shall not deviate from the setting values by more than ± 5 rpm for the output speed.

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4.4.5.2 The averaged output torque values as described under 4.4.3 for each grid point shall not deviate more than ± 20 Nm or ± 1 % from the torque set point for the according grid point, whichever is the higher value.

4.4.5.3 If the above specified criteria are not met the measurement is void. In this case, the measurement for the entire affected speed step shall be repeated. After passing the repeated measurement, the data shall be consolidated.

4.4.6 Uncertainty calculation

The total uncertainty $U_{T,loss}$ of the torque loss shall be calculated based on the following parameters:

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i. Temperature effect

ii. Parasitic loads

iii. Uncertainty (incl. sensitivity tolerance, linearity, hysteresis and repeatability)

The total uncertainty of the torque loss ($U_{T,loss}$) is based on the uncertainties of the sensors at 95 % confidence level. The calculation shall be done for each applied sensor (e.g. three machine lay out: $U_{T,in}$, $U_{T,out,1}$, $U_{Tout,2}$) as the square root of the sum of squares ('Gaussian law of error propagation').

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$$U_{T,in/out} = 2 \times \sqrt{U_{TKC}^2 + U_{TK0}^2 + U_{cal}^2 + U_{para}^2}$$

$$U_{TKC} = \frac{1}{\sqrt{3}} \times \frac{w_{tkc}}{K_{ref}} \times \Delta K \times T_c$$

$$U_{TK0} = \frac{1}{\sqrt{3}} \times \frac{w_{tk0}}{K_{ref}} \times \Delta K \times T_n$$

$$U_{cal} = 1 \times \frac{w_{cal}}{k_{cal}} \times T_n$$

$$U_{para} = \frac{1}{\sqrt{3}} \times w_{para} \times T_n$$

$$w_{para} = sens_{para} * i_{para}$$

where:

$U_{T,in/out}$ = Uncertainty of input/output torque loss measurement separately for input and output torque; [Nm]

i_{gear} = Axle gear ratio [-]

U_{TKC} = Uncertainty by temperature influence on current torque signal; [Nm]

w_{tkc} = Temperature influence on current torque signal per K_{ref}, declared by sensor manufacturer; [%]

U_{TK0} = Uncertainty by temperature influence on zero torque signal (related to nominal torque) [Nm]

w_{tk0} = Temperature influence on zero torque signal per K_{ref} (related to nominal torque), declared by sensor manufacturer; [%]

K_{ref} = Reference temperature span for tkc and tk0, declared by sensor manufacturer; [°C]

ΔK = Absolute difference in sensor temperature measured at torque sensor between calibration and measurement; If the sensor temperature cannot be measured, a default value of ►M3 ΔK = 15 ◄ shall be used [°C]

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T_c = Current/measured torque value at 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)

U_{para} = Uncertainty by parasitic loads; [Nm]

w_{para} = $sens_{para} * i_{para}$

Relative influence of forces and bending torques caused by misalignment

$sens_{para}$ = Maximum influence of parasitic loads for specific torque sensor declared by sensor manufacturer [%]; if no specific value for parasitic loads is declared by the sensor manufacturer, the value shall be set to 1,0 %

i_{para} = Maximum influence of parasitic loads for specific torque sensor depending on test set-up as indicated in section 4.2.3 and 4.2.4 of this annex.

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4.4.7 Assessment of total uncertainty of the torque loss

In the case the calculated uncertainties $U_{T,in/out}$ are below the following limits, the reported torque loss $T_{loss,rep}$ shall be regarded as equal to the measured torque loss T_{loss}.

$U_{T,in}$: 7,5 Nm or 0,25 % of the measured torque, whichever allowed uncertainty value is higher

For test setups with one dynamometer on the output side:

$U_{T,out}$: 15 Nm or 0,25% of the measured torque, whichever allowed uncertainty value is higher

For test setups with two dynamometers on each output side:

$U_{T,out}$: 7,5 Nm or 0,25% of the measured torque, whichever allowed uncertainty value is higher

In the case of higher calculated uncertainties, the part of the calculated uncertainty exceeding the above specified limits shall be inserted to T_{loss} for the reported torque loss $T_{loss,rep}$ as follows:

If the limits of $U_{T,in}$ are exceeded:

$$T_{loss,rep} = T_{loss} + \Delta UT_{in}$$

$$\Delta U_{T,in} = MIN((U_{T,in} - 0{,}25\% \times T_c) \text{ or } (U_{T,in} - 7{,}5\ Nm))$$

If limits of $U_{T,out}$ out are exceeded:

$$T_{loss,rep} = T_{loss} + \Delta U_{T,out} / i_{gear}$$

For test setups with one dynamometer on the output side:

$$\Delta U_{T,out} = MIN((U_{T,out} - 0{,}25\% \times T_c) \text{ or } (U_{T,out} - 15Nm))$$

For test setups with two dynamometers on each output side:

$$\Delta U_{T,out} = \sqrt{(\Delta U_{T,out\ 1})^2 + (\Delta U_{T,out\ 2})^2}$$

$$\Delta U_{T,out\_1} = MIN((U_{T,out\_1} - 0{,}25\% \times T_c) \text{ or } (U_{T,out\_1} - 7{,}5Nm))$$

$$\Delta U_{T,out\_2} = MIN((U_{T,out\_1} - 0{,}25\% \times T_c) \text{ or } (U_{T,out\_1} - 7{,}5Nm))$$

▼M3

where:

$U_{T,in/out}$ = Uncertainty of input / output torque loss measurement separately for input and output torque; [Nm]

i_{gear} = Axle gear ratio [-]

ΔU_T = The part of the calculated uncertainty exceeding the specified limits

▼B

4.4.8 Complement of torque loss map data

4.4.8.1 If the torque values exceed the upper range limit linear extrapolation shall be applied. For the extrapolation the slope of linear regression based on all measured torque points for the corresponding speed step shall be applied.

▼M3

4.4.8.2 For the output torque range values below the lowest measured grid point as defined in section 4.3.3.2, the torque loss values of the lowest measured grid point shall be applied.

▼B

4.4.8.3 For 0 rpm wheel speed rpm the torque loss values of the 50 rpm speed step shall be applied.

4.4.8.4 For negative input torques (e.g. overrun, free rolling), the torque loss value measured for the related positive input torque shall be applied.

▼M1

4.4.8.5 In case of a tandem axle, the combined torque loss map for both axles shall be calculated out of the test results for the single axles at the input side. The input torques shall also be added.

$$T_{loss,rep,tdm} = T_{loss,rep,1} + T_{loss,rep,2}$$

$$T_{in,tdm} = T_{in,1} + T_{in,2}$$

▼B

5. Conformity of the certified CO_2 emissions and fuel consumption related properties

5.1. Every axle type approved in accordance with this Annex shall be so manufactured as to conform, with regard to the description as given in the certification form and its annexes, to the approved type. ►M3 The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply with those set out in Article 31 of Regulation (EU) 2018/858. ◄

5.2. Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificate set out in Appendix 1 to this Annex and the specific conditions laid down in this paragraph.

5.3. The manufacturer shall test annually at least the number of axles indicated in Table 1 based on the annual production numbers. For the purpose of establishing the production numbers, only axles which fall under the requirements of this Regulation shall be considered.

5.4. Each axle which is tested by the manufacturer shall be representative for a specific family.

5.5. The number of families of single reduction (SR) axles and other axles for which the tests shall be conducted is shown in Table 1.

▼B

Table 1

Sample size for conformity testing

Production number	Number of test for SR axles	Number of tests for other axles than SR axles
0 – 40 000	2	1
40 001 – 50 000	2	2
50 001 – 60 000	3	2
60 001 – 70 000	4	2
70 001 – 80 000	5	2
80 001 and more	5	3

5.6. The two axle families with the highest production volumes shall always be tested. The manufacturer shall justify (e.g. by showing sales numbers) to the approval authority the number of tests which has been performed and the choice of the families. The remaining families for which the tests are to be performed shall be agreed between the manufacturer and the approval authority.

5.7. For the purpose of the conformity of the certified CO_2 emissions and fuel consumption related properties testing the approval authority shall identify together with the manufacturer the axle type(s) to be tested. The approval authority shall ensure that the selected axle type(s) are manufactured according to the same standards as for serial production.

5.8. If the result of a test performed in accordance with point 6 is higher than the one specified in point 6.4, three additional axles from the same family shall be tested. If at least one of them fails, provisions of Article 23 shall apply.

6. Production conformity testing

6.1 For conformity of the certified CO_2 emissions and fuel consumption related properties testing, one of the following methods shall apply upon prior agreement between the approval authority and the applicant for a certificate:

(a) Torque loss measurement according to this Annex by following the full procedure limited to the grid points described in 6.2.

(b) Torque loss measurement according to this Annex by following the full procedure limited to the grid points described in 6.2, with exception of the run-in procedure. In order to consider the run-in characteristic of an axle, a corrective factor may be applied. This factor shall be determined according to good engineering judgement and with agreement of the approval authority.

(c) Measurement of drag torque according to paragraph 6.3. The manufacturer may choose a run-in procedure according to good engineering judgement up to 100 h.

6.2 If the conformity of the certified CO_2 emissions and fuel consumption related properties assessment is performed according to 6.1. a) or b) the grid points for this measurement are limited to 4 grid points from the approved torque loss map.

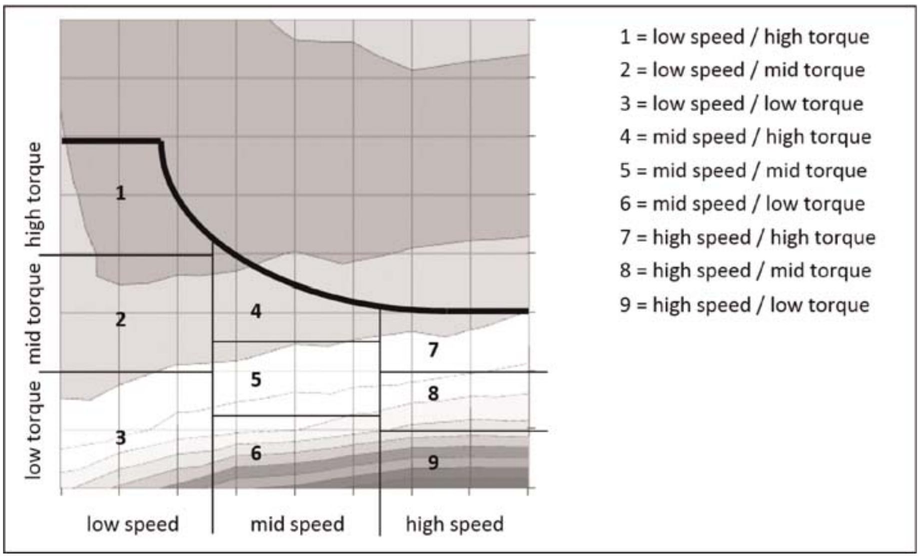
▼B

6.2.1 For that purpose the full torque loss map of the axle to be tested for conformity of the certified CO_2 emissions and fuel consumption related properties shall be segmented into three equidistant speed ranges and three torque ranges in order to define nine control areas as shown in figure 2.

▼M1

Figure 2

Speed and torque range for conformity of the certified CO_2 emissions and fuel consumption related properties testing



▼B

6.2.2 For four control areas one point shall be selected, measured and evaluated according to the full procedure as described in section 4.4. Each control point shall be selected in the following manner:

(i) The control areas shall be selected depending on the axle line:

— SR axles including tandem combinations: Control areas 5, 6, 8 and 9

— HR axles including tandem combinations: Control areas 2, 3, 4 and 5

(ii) The selected point shall be located in the centre of the area referring to the speed range and the applicable torque range for the according speed.

(iii) In order to have a corresponding point for comparison with the loss map measured for certification, the selected point shall be moved to the closest measured point from the approved map. ►M3 If the selected point is in the middle between two approved points, the higher point shall be used. ◄

6.2.3 For each measured point of the conformity of the certified CO_2 emissions and fuel consumption related properties test and its corresponding point of the type approved map, the efficiency shall be calculated with:

▼B

$$\eta_i = \frac{T_{out}}{\mathrm{i}_{\mathrm{axle}} \times T_{in}}$$

where:

η_i = Efficiency of the grid point from each single control area 1 to 9

T_{out} = Output torque [Nm]

T_{in} = Input torque [Nm]

$\mathrm{i}_{\mathrm{axle}}$ = axle ratio [-]

6.2.4 The average efficiency of the control area shall be calculated as follows:

For SR axles:

$$\eta_{avr,mid\ speed} = \frac{\eta_5 + \eta_6}{2}$$

$$\eta_{avr,high\ speed} = \frac{\eta_8 + \eta_9}{2}$$

$$\eta_{avr,total} = \frac{\eta_{avr,mid\ speed} + \eta_{avr,high\ speed}}{2}$$

For HR axles:

$$\eta_{avr,low\ speed} = \frac{\eta_2 + \eta_3}{2}$$

$$\eta_{avr,mid\ speed} = \frac{\eta_4 + \eta_5}{2}$$

$$\eta_{avr,total} = \frac{\eta_{avr,low\ speed} + \eta_{avr,mid\ speed}}{2}$$

where:

$\eta_{avr,low\ speed}$ = average efficiency for low speed

$\eta_{avr,mid\ speed}$ = average efficiency for mid speed

$\eta_{avr,high\ speed}$ = average efficiency for high speed

$\eta_{avr,total}$ = simplified averaged efficiency for axle

6.2.5 If the conformity of the certified CO_2 emissions and fuel consumption related properties assessment is performed in accordance with 6.1. c), the drag torque of the parent axle of the family to which the tested axle belongs shall be determined during the certification. ►M3 This can be done prior to the run-in procedure or after the run-in procedure in accordance with point 3.1 or by extrapolation of all the torque map values for each speed step downwards to 0 Nm. The extrapolation shall be linear or a polynomial second order, depending which standard deviation is lower. ◄

▼**B**

6.3 Determination of drag torque

6.3.1 For determination of the drag torque of an axle a simplified test set-up with one electric machine and one torque sensor on the input side is required. ►**M3** In the event of a single portal axle with different length of the two output shafts, a test setup with two electric machines and two torque sensors on each output is also permitted. In this respect, both output shafts are driven synchronously in driving direction. The final drag torque is represented by the sum of both output torques. ◄

6.3.2 The test conditions according to paragraph 4.1 shall apply. The uncertainty calculation regarding torque may be omitted.

6.3.3 The drag torque shall be measured in the speed range of the approved type according to paragraph 4.3.4 under consideration of the speed steps according to 4.3.5.

6.4. Conformity of the certified CO_2 emissions and fuel consumption related properties test assessment

6.4.1 A conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when one of the following conditions apply:

▼**M1**

(a) If a torque loss measurement in accordance with points 6.1(a) or (b) is conducted, the average efficiency of the tested axle during conformity of the certified CO_2 emissions and fuel consumption related properties procedure shall not be lower than 1,5 % for SR axles and 2,0 % for all other axles lines below the corresponding average efficiency of the type approved axle.

(b) If a measurement of drag torque in accordance with point 6.1(c) is conducted, the drag torque of the tested axle during conformity of the certified CO_2 emissions and fuel consumption related properties procedure shall be lower than the corresponding drag torque of the type approved axle or within the tolerance indicated in Table 2.

▼**M3**

Table 2

Axleline	Tolerances for axles measured in CoP after run-in Comparison to Td0				Tolerances for axles measured in CoP without run in Comparison to Td0			
	for i	tolerance Td0_input [Nm]	for i	tolerance Td0_input [Nm]	for i	tolerance Td0_input Nm]	for i	tolerance Td0_input [Nm]
SR	≤ 3	10	> 3	9	> 3	16	> 3	15
SRT	≤ 3	11	> 3	10	> 3	18	> 3	16
SP	≤ 6	11	> 6	10	> 6	18	> 6	16
HR	≤ 7	15	> 7	12	> 7	25	> 7	20
HRT	≤ 7	16	> 7	13	> 7	27	> 7	21

i = gear ratio

▼B

Appendix 1

MODEL OF A CERTIFICATE OF A COMPONENT, SEPARATE TECHNICAL UNIT OR SYSTEM

Maximum format: A4 (210 × 297 mm)

CERTIFICATE ON CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF AN AXLE FAMILY

Communication concerning:	Administration stamp

— granting [1]

— extension [1]

— refusal [1]

— withdrawal [1]

of a certificate on CO_2 emission and fuel consumption related properties of an axle family in accordance with Commission Regulation (EU) 2017/2400.

Commission Regulation (EU) 2017/2400 as last amended by ....

Certification number:

Hash:

Reason for extension:

SECTION I

0.1 Make (trade name of manufacturer):

0.2 Type:

0.3 Means of identification of type, if marked on the axle

0.3.1 Location of the marking:

0.4 Name and address of manufacturer:

0.5 In the case of components and separate technical units, location and method of affixing of the EC certification mark:

0.6 Name(s) and address(es) of assembly plant(s):

0.7 Name and address of the manufacturer's representative (if any)

SECTION II

1. Additional information (where applicable): see Addendum

2. Approval authority responsible for carrying out the tests:

3. Date of test report

4. Number of test report

5. Remarks (if any): see Addendum

6. Place

7. Date

8. Signature

Attachments:

1. Information document

2. Test report

[1] Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable)

▼B

Appendix 2

Axle information document

Information document no.: Issue:

Date of issue:

Date of Amendment:

pursuant to …

▼M1

Axle type/family (if applicable):

▼B

…

▼**B**

0. GENERAL

0.1 Name and address of manufacturer

0.2 Make (trade name of manufacturer):

0.3 Axle type:

0.4 Axle family (if applicable):

0.5 Axle type as separate technical unit / Axle family as separate technical unit

0.6 Commercial name(s) (if available):

0.7 Means of identification of type, if marked on the axle:

0.8 In the case of components and separate technical units, location and method of affixing of the certification mark:

0.9 Name(s) and address(es) of assembly plant(s):

0.10 Name and address of the manufacturer's representative:

▼B

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) AXLE AND THE AXLE TYPES WITHIN AN AXLE FAMILY

		Parent axle or axle type	Family member #1	#2	#3

▼M1

____

▼B

1.0	SPECIFIC AXLE INFORMATION				
1.1	Axle line (SR, HR, SP, SRT, HRT)	…	…	…	…
1.2	Axle gear ratio	…	…	…	…

▼M3

1.3 Axle housing (drawing)

▼B

1.4	Gear specifications	…	…	…	
1.4.1	Crown wheel diameter; [mm]	…	…		
1.4.2	Vertical offset pinion/crown wheel; [mm]	…			

1.4.3 Pinion angle with respect to horizontal plane; [°]

1.4.4 For portal axles only:

Angle between pinion axle and crown wheel axle; [°]

1.4.5 Teeth number of pinion

1.4.6 Teeth number of crown gear

1.4.7 Horizontal offset of pinion; [mm]

1.4.8 Horizontal offset of crown wheel; [mm]

▼M3

1.5 Oil volume(s); [cm^3]

1.6 Oil level(s); [mm]

▼B

1.7 Oil specification

▼M3

1.8 Bearing type (type, quantity, inner diameter, outer diameter, width and drawing)

1.9 Seal type (main diameter, lip quantity); [mm]

1.10 Wheel ends (drawing)

1.10.1 Bearing type (type, quantity, inner diameter, outer diameter, width and drawing)

1.10.2 Seal type (main diameter, lip quantity); [mm]

▼B

1.10.3 Grease type

▼M3

1.11 Number of planetary / spur gears for differential carrier

1.12 Smallest width of planetary/ spur gears for differential carrier; [mm]

▼B

1.13 Gear ratio of hub reduction

▼B

LIST OF ATTACHMENTS

No.:	**Description:**	**Date of issue:**
1	…	…
2	…	

▼M3

Appendix 3

Calculation of the standard torque loss

The standard torque losses for axles are shown in Table 1. The standard table values consist of the sum of a generic constant efficiency value covering the load dependent losses and a generic basic drag torque loss to cover the drag losses at low loads.

Tandem axles shall be calculated using a combined efficiency for an axle including drive-thru (SRT, HRT) plus the matching single axle (SR, HR).

Table 1

Generic efficiency and drag loss

Basic function	Generic efficiency η	Drag torque (wheel side) $T_{d0} = T_0 + T_1 \times i_{gear}$
Single reduction axle (SR)	0,98	T_0 = 70 Nm T_1 = 20 Nm
Single reduction tandem axle (SRT) / single portal axle (SP)	0,96	T_0 = 80 Nm T_1 = 20 Nm
Hub reduction axle (HR)	0,97	T_0 = 70 Nm T_1 = 20 Nm
Hub reduction tandem axle (HRT)	0,95	T_0 = 90 Nm T_1 = 20 Nm
All other axle technologies	0,90	T_0 = 150 Nm T_1 = 50 Nm

The basic drag torque (wheel side) T_{d0} is calculated by

$$T_{d0} = T_0 + T_1 \times i_{gear}$$

using the values from Table 1.

The standard torque loss $T_{loss,std}$ on the input side of the axle is calculated by

$$T_{loss,std} = \frac{T_{d0} + \frac{T_{out}}{\eta} - T_{out}}{i_{gear}}$$

where:

$T_{loss,std}$ = Standard torque loss at the input side [Nm]

T_{d0} = Basis drag torque over the complete speed range [Nm]

i_{gear} = Axle gear ratio [-]

η = Generic efficiency for load dependent losses [-]

T_{out} = torque [Nm]

The corresponding torque (at input side) of the axle shall be calculated by

$$T_{in} = \frac{T_{out}}{i_{gear}} + T_{loss,std}$$

where:

T_{in} = Input torque [Nm]

▼B

Appendix 4

Family Concept

1. The applicant for a certificate shall submit to the approval authority an application for a certificate for an axle family based on the family criteria as indicated in paragraph 3.

An axle family is characterized by design and performance parameters. These shall be common to all axles within the family. The axle manufacturer may decide which axle belongs to an axle family, as long as the family criteria of paragraph 4 are respected. In addition to the parameters listed in paragraph 4, the axle manufacturer may introduce additional criteria allowing the definition of families of more restricted size. These parameters are not necessarily parameters that have an influence on the level of performance. The axle family shall be approved by the approval authority. The manufacturer shall provide to the approval authority the appropriate information relating to the performance of the members of the axle family.

2. Special cases

In some cases there may be interaction between parameters. This shall be taken into consideration to ensure that only axles with similar characteristics are included within the same axle family. These cases shall be identified by the manufacturer and notified to the approval authority. It shall then be taken into account as a criterion for creating a new axle family.

In case of parameters, which are not listed in paragraph 3 and which have a strong influence on the level of performance, this parameters shall be identified by the manufacturer on the basis of good engineering practice, and shall be notified to the approval authority.

3. Parameters defining an axle family:

3.1 Axle category

(a) Single reduction axle (SR)

(b) Hub reduction axle (HR)

(c) Single portal axle (SP)

(d) Single reduction tandem axle (SRT)

(e) Hub reduction tandem axle (HRT)

(f) Same inner axle housing geometry between differential bearings and horizontal plane of centre of pinion shaft according to drawing specification (Exception for single portal axles (SP)). Geometry changes due to an optional integration of a differential lock are permitted within the same axle family. In case of mirror inverted axle casings of axles, the mirror inverted axles can be combined in the same axle family as the origin axles, under the premise, that the bevel gear sets are adapted to the other running direction (change of spiral direction).

▼M1

(g) Crown wheel diameter (+ 1,5 %/– 8 % ref. to the largest drawing diameter)

▼B

(h) Vertical hypoid offset pinion/crown wheel within ± 2 mm

(i) In case of single portal axles (SP): Pinion angle with respect to horizontal plane within ± 5°

▼B

(j) In case of single portal axles (SP): Angle between pinion axle and crown wheel axle within ± 3,5°

(k) In case of hub reduction and single portal axles (HR, HRT, FHR, SP): Same number of planetary gear and spur wheels

▼M1

(l) Gear ratio of every gear step within an axle in a range of 2, as long as only one gear set is changed

▼B

(m) Oil level within ± 10 mm or oil volume ± 0,5 litre referring to drawing specification and the installation position in the vehicle

(n) Same oil type viscosity grade (recommended factory fill)

▼M3

(o) Type of bearings (inner diameter, outer diameter and width) at corresponding positions (if fitted) within ±1 mm of drawing reference

(p) Type of sealing

▼B

4. Choice of the parent axle:

4.1 The parent axle within an axle family is determined as the axle with the highest axle ratio. In case of more than two axles having the same axle ratio, the manufacturer shall provide an analysis in order to determine the worst-case axle as parent axle.

4.2. The approval authority may conclude that the worst-case torque loss of the family can best be characterized by testing additional axles. In this case, the axle manufacturer shall submit the appropriate information to determine the axle within the family likely to have the highest torque loss level.

4.3. If axles within the family incorporate other features which may be considered to affect the torque losses, these features shall also be identified and taken into account in the selection of the parent axle.

▼B

Appendix 5

Markings and numbering

1. Markings

In the case of an axle being type approved accordant to this Annex, the axle shall bear:

▼M1

1.1. The manufacturer's name or trade mark

▼B

1.2 The make and identifying type indication as recorded in the information referred to in paragraph 0.2 and 0.3 of Appendix 2 to this Annex

1.3 The certification mark as a rectangle surrounding the lower-case letter ‘e’ followed by the distinguishing number of the Member State which has granted the certificate:

1 for Germany;

2 for France;

3 for Italy;

4 for the Netherlands;

5 for Sweden;

6 for Belgium;

7 for Hungary;

8 for the Czech Republic;

9 for Spain;

11 for the United Kingdom;

12 for Austria;

13 for Luxembourg;

17 for Finland;

18 for Denmark;

19 for Romania;

20 for Poland;

21 for Portugal;

23 for Greece;

24 for Ireland;

25 for Croatia;

26 for Slovenia;

27 for Slovakia;

29 for Estonia;

32 for Latvia;

34 for Bulgaria;

36 for Lithuania;

49 for Cyprus;

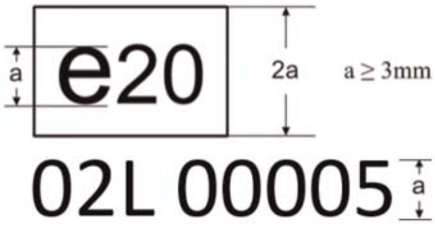
50 for Malta

1.4 ►M3 The certification mark shall also include in the vicinity of the rectangle the ‘base certification number’ as specified for Section 4 of the type- approval number set out in Annex IV to Regulation (EU) 2020/683, preceded by the two figures indicating the sequence number assigned to the latest technical amendment to this Regulation and by a character ‘*L*’ indicating that the certificate has been granted for an axle.

For this Regulation, the sequence number shall be 02. ◄

▼M3

1.4.1 Example and dimensions of the certification mark



▼M3

The above certification mark affixed to an axle shows that the type concerned has been approved in Poland (e20), pursuant to this Regulation. The first two digits (02) are indicating the sequence number assigned to the latest technical amendment to this Regulation. The following letter indicates that the certificate was granted for an axle (L). The last five digits (00005) are those allocated by the type-approval authority to the axle as the base certification number.

▼B

1.5 Upon request of the applicant for a certificate and after prior agreement with the type-approval authority other type sizes than indicated in 1.4.1 may be used. Those other type sizes shall remain clearly legible.

1.6 The markings, labels, plates or stickers must be durable for the useful life of the axle and must be clearly legible and indelible. The manufacturer shall ensure that the markings, labels, plates or sticker cannot be removed without destroying or defacing them.

1.7 The certification number shall be visible when the axle is installed on the vehicle and shall be affixed to a part necessary for normal operation and not normally requiring replacement during component life.

2. Numbering:

▼M3

2.1 Certification number for axles shall comprise the following:

eX*YYYY/YYYY*ZZZZ/ZZZZ*L*00000*00

section 1	section 2	section 3	Additional letter to section 3	section 4	section 5
Indication of country issuing the certificate	HDV CO_2 determination Regulation ‘2017/2400’	Latest amending Regulation (ZZZZ/ZZZZ)	L = Axle	Base certification number 00000	Extension 00

▼B

Appendix 6

Input parameters for the simulation tool

Introduction

This Appendix describes the list of parameters to be provided by the component manufacturer as input to the simulation tool. The applicable XML schema as well as example data are available at the dedicated electronic distribution platform.

Definitions

▼M1

(1) 'Parameter ID': Unique identifier as used in the simulation tool for a specific input parameter or set of input data

▼B

(2) 'Type': Data type of the parameter

string .... sequence of characters in ISO8859-1 encoding

token .... sequence of characters in ISO8859-1 encoding, no leading/trailing whitespace

date .... date and time in UTC time in the format: YYYY-MM-DD***T***HH:MM:SS***Z*** with italic letters denoting fixed characters e.g. '2002-05-30T09:30:10Z'

integer .... value with an integral data type, no leading zeros, e.g. '1800'

double, X .... fractional number with exactly X digits after the decimal sign ('.') and no leading zeros e.g. for 'double, 2': '2345.67'; for 'double, 4': '45.6780'

(3) 'Unit' … physical unit of the parameter

Set of input parameters

Table 1

Input parameters 'Axlegear/General'

Parameter name	Param ID	Type	Unit	Description/Reference
Manufacturer	P215	token	[-]	
Model	P216	token	[-]	
▼M1 Certification-Number	P217	token	[-]	
▼B Date	P218	dateTime	[-]	Date and time when the component-hash is created

▼B

Parameter name	Param ID	Type	Unit	Description/Reference
AppVersion	P219	token	[-]	
LineType	P253	string	[-]	Allowed values: ‘Single reduction axle’, ‘Single portal axle’, ‘Hub reduction axle’, ‘Single reduction tandem axle’, ‘Hub reduction tandem axle’
Ratio	P150	double, 3	[-]	
Certification-Method	P256	string	[-]	Allowed values: ‘Measured’, ‘Standard values’

Table 2

Input parameters ‘Axlegear/LossMap’ for each grid point in the loss map

Parameter name	Param ID	Type	Unit	Description/Reference
InputSpeed	P151	double, 2	[1/min]	
InputTorque	P152	double, 2	[Nm]	
TorqueLoss	P153	double, 2	[Nm]	

▼B

ANNEX VIII

VERIFYING AIR DRAG DATA

▼M3

1. Introduction

This Annex sets out the test procedures for the determination of air drag data.

▼B

2. Definitions

For the purposes of this Annex the following definitions shall apply:

(1) 'Active aero device' means measures which are activated by a control unit to reduce the air drag of the total vehicle.

(2) 'Aero accessories' mean optional devices which have the purpose to influence the air flow around the total vehicle.

(3) 'A-pillar' means the connection by a supporting structure between the cabin roof and the front bulkhead.

(4) 'Body in white geometry' means the supporting structure incl. the windshield of the cabin.

(5) 'B-pillar' means the connection by a supporting structure between the cabin floor and the cabin roof in the middle of the cabin.

(6) 'Cab bottom' means the supporting structure of the cabin floor.

(7) 'Cabin over frame' means distance from frame to cabin reference point in vertical Z. Distance is measured from top of horizontal frame to cabin reference point in vertical Z.

(8) 'Cabin reference point' means the reference point (X/Y/Z = 0/0/0) from the CAD coordinate system of the cabin or a clearly defined point of the cabin package e.g. heel point.

(9) 'Cabin width' means the horizontal distance of the left and right B-pillar of the cabin.

(10) 'Constant speed test' means measurement procedure to be carried out on a test track in order to determine the air drag.

(11) 'Dataset' means the data recorded during a single passing of a measurement section.

(12) 'EMS' means the European Modular System (EMS) in accordance with Council Directive 96/53/EC.

(13) 'Frame height' means distance of wheel center to top of horizontal frame in Z.

▼B

(14) 'Heel point' means the point which is representing the heel of shoe location on the depressed floor covering, when the bottom of shoe is in contact with the undepressed accelerator pedal and the ankle angle is at 87°. (ISO 20176:2011)

(15) 'Measurement area(s)' means designated part(s) of the test track consisting of at least one measurement section and a preceded stabilisation section.

(16) 'Measurement section' means a designated part of the test track which is relevant for data recording and data evaluation.

(17) 'Roof height' means distance in vertical Z from cabin reference point to highest point of roof w/o sunroof

3. Determination of air drag

The constant speed test procedure shall be applied to determine the air drag characteristics. During the constant speed test the main measurement signals driving torque, vehicle speed, air flow velocity and yaw angle shall be measured at two different constant vehicle speeds (low and high speed) under defined conditions on a test track. The measurement data recorded during the constant speed test shall be entered into the air drag pre-processing tool which determines product of drag coefficient by cross sectional area for zero crosswind conditions $C_d \cdot A_{cr}\ (0)$ as input for the simulation tool. The applicant for a certificate shall declare a value $C_d \cdot A_{declared}$ in a range from equal up to a maximum of + 0,2 m^2 higher than $C_d \cdot A_{cr}\ (0)$. ►M3 The value $C_d{\cdot}A_{declared}$ shall be the input for the simulation tool and the reference value for conformity of the certified CO_2 emissions and fuel consumption related properties testing. ◄

▼M1

Vehicles which are not member of a family shall use the standard values for $C_d{\cdot}A_{declared}$ as described in Appendix 7 to this Annex. In this case no input data on air drag shall be provided. The allocation of standard values is done automatically by the simulation tool.

▼B

3.1. Test track requirements

3.1.1. The geometry of test track shall be either a:

i. Circuit track (drivable in one direction (*)):

with two measurement areas, one on each straight part, with maximum deviation of less than 20 degrees);

(*) At least for the misalignment correction of the mobile anemometer (see 3.6) the test track has to be driven in both directions

or

ii. Circuit or straight line track (drivable in both directions):

with one measurement area (or two with the above named maximum deviation); two options: alternating driving direction after each test section; or after a selectable set of test sections e.g. ten times driving direction 1 followed by ten times driving direction 2.

▼B

3.1.2. Measurement sections

On the test track measurement section(s) of a length of 250 m with a tolerance of ± 3 m shall be defined.

3.1.3. Measurement areas

A measurement area shall consist of at least one measurement section and a stabilisation section. The first measurement section of a measurement area shall be preceded by a stabilisation section to stabilise the speed and torque. The stabilisation section shall have a length of minimum 25 m. The test track layout shall enable that the vehicle enters the stabilisation section already with the intended maximum vehicle speed during the test.

Latitude and longitude of start and end point of each measurement section shall be determined with an accuracy of better or equal 0,15 m 95 % Circular Error Probable (DGPS accuracy).

3.1.4. Shape of the measurement sections

The measurement section and the stabilization section have to be a straight line.

3.1.5. Longitudinal slope of the measurement sections

The average longitudinal slope of each measurement and the stabilisation section shall not exceed ± 1 per cent. Slope variations on the measurement section shall not lead to velocity and torque variations above the thresholds specified in 3.10.1.1 items vii. and viii. of this Annex.

3.1.6. Track surface

The test track shall consist of asphalt or concrete. The measurement sections shall have one surface. Different measurement sections are allowed to have different surfaces.

3.1.7. Standstill area

There shall be a standstill area on the test track where the vehicle can be stopped to perform the zeroing and the drift check of the torque measurement system.

3.1.8. Distance to roadside obstacles and vertical clearance

There shall be no obstacles within 5 m distance to both sides of the vehicle. Safety barriers up to a height of 1 m with more than 2,5 m distance to the vehicle are permitted. Any bridges or similar constructions over the measurement sections are not allowed. The test track shall have enough vertical clearance to allow the anemometer installation on the vehicle as specified in 3.4.7 of this Annex.

3.1.9. Altitude profile

The manufacturer shall define whether the altitude correction shall be applied in the test evaluation. In case an altitude correction is applied, for each measurement section the altitude profile shall be made available. The data shall meet the following requirements:

i. The altitude profile shall be measured at a grid distance of lower or equal than 50 m in driving direction.

ii. For each grid point the longitude, the latitude and the altitude shall be measured at least at one point ('altitude measurement point') on each side of the centre line of the lane and then be processed to an average value for the grid point.

▼B

iii. The grid points as provided to the air drag pre-processing tool shall have a distance to the centre line of the measurement section of less than 1 m.

iv The positioning of the altitude measurement points to the centre line of the lane (perpendicular distance, number of points) shall be chosen in a way that the resulting altitude profile is representative for the gradient driven by the test vehicle.

v. The altitude profile shall have an accuracy of ± 1cm or better.

vi. The measurement data shall not be older than 10 years. A renewal of the surface in the measurement area requires a new altitude profile measurement.

3.2. Requirements for ambient conditions

3.2.1. The ambient conditions shall be measured with the equipment specified in 3.4.

3.2.2. The ambient temperature shall be in the range of 0 °C to 25 °C. This criterion is checked by the air drag pre-processing tool based on the signal for ambient temperature measured on the vehicle. This criterion only applies to the datasets recorded in the low speed - high speed – low speed sequence and not to the misalignment test and the warm-up phases.

3.2.3. The ground temperature shall not exceed 40 °C. This criterion is checked by the air drag pre-processing tool based on the signal for ground temperature measured on the vehicle by an IR Sensor. This criterion only applies to the datasets recorded in the low speed - high speed – low speed sequence and not to the misalignment test and the warm-up phases.

3.2.4. The road surface shall be dry during the low speed – high speed - low speed sequence to provide comparable rolling resistance coefficients.

3.2.5. The wind conditions shall be within the following range:

i. Average wind speed: ≤ 5 m/s

ii. Gust wind speed (1s central moving average): ≤ 8 m/s

Items i. and ii. are applicable for the datasets recorded in the high speed test and the misalignment calibration test but not for the low speed tests.

iii. Average yaw angle (β):

≤ 3 degrees for datasets recorded in the high speed test

≤ 5 degrees for datasets recorded during misalignment calibration test

The validity of wind conditions is checked by the air drag pre-processing based on the signals recorded at the vehicle after application of the boundary layer correction. Measurement data collected under conditions exceeding the above named limits are automatically excluded from the calculation.

▼M3

3.3. Installation of the vehicle

3.3.1. General installation requirements

3.3.1.1. The vehicle tested shall represent the vehicle to be placed on the market, in accordance with the requirements for vehicle type approval in accordance with Regulation (EU) 2018/858. Equipment which is necessary to execute the constant speed test (e.g. overall vehicle height including anemometer) is excluded from this provision.

3.3.1.2. The vehicle shall be equipped with tyres meeting the following criteria:

— Best or second best label for fuel efficiency which is available at the moment the test is performed;

— Maximum tread depth of 10 mm on all tyres of the complete vehicle, including the trailer (if applicable);

— Tyres inflated within a tolerance of ± 20 kPa of the pressure marked on the tyre sidewall in accordance with Article 3 of UN Regulation No. 54 ([1]).

3.3.1.3. The axle alignment shall be within the manufacturer's specifications.

3.3.1.4. No active tyre pressure control systems are allowed to be used during the measurements of the low speed - high speed - low speed tests.

3.3.1.5. If the vehicle is equipped with an active aero device, the device may be active during the constant speed test under the following conditions:

— it has been demonstrated to the approval authority that the device is always activated and effective to reduce the air drag at vehicle speeds higher than 60 km/h for medium and heavy lorries and higher than 80 km/h for heavy buses;

— the device is installed and effective in a similar manner on all vehicles of the family.

In all other cases the active aero device has to be fully deactivated during the constant speed test.

3.3.1.6. The vehicle shall not be equipped with any provisional features, modifications or devices that are not representative for the vehicle in use, aimed to reducing the air drag value during the test (e.g. sealed bodywork gaps). Modifications which aim to align the aerodynamic characteristics of the tested vehicle to the specifications of the parent vehicle are allowed.

3.3.1.7. Aftermarket parts, i.e. parts which are not covered by the vehicle type approval in accordance with Regulation 2018/858 (e.g. sun visors, horns, additional head lights, signal lights, bull bars or ski-boxes) are not considered for the air drag in accordance with this Annex.

3.3.1.8. The vehicle shall be measured without payload.

3.3.2. Installation requirements applicable for medium and heavy rigid lorries

([1]) Regulation No 54 of the Economic Commission for Europe of the United Nations (UNECE) – Uniform provisions concerning the approval of pneumatic tyres for commercial vehicles and their trailers (OJ L 183, 11.7.2008, p. 41).

▼M3

3.3.2.1. The vehicle chassis shall fit to the dimensions of the standard body or semi-trailer as defined in Appendix 4 of this Annex.

3.3.2.2. The vehicle height determined in accordance with 3.5.3.1 item vii shall be within the limits as specified in Appendix 3 of this Annex.

3.3.2.3. The minimum distance between the cabin and the box body or semi-trailer shall be in accordance with the manufacturer's requirements and body builder's instructions.

3.3.2.4. The cabin and the aero accessories shall be adapted to best fit to the defined standard body or semi-trailer. The installation of the aero accessories (e.g. spoiler) shall be in accordance with the instructions of the manufacturer.

3.3.2.5. The setup of the semi-trailer shall be as defined in Appendix 4 of this Annex.

▼B

3.4. Measurement equipment

The calibration laboratory shall comply with the requirements of either ►M3 IATF ◄ 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.

3.4.1. Torque

3.4.1.1. The direct torque at all driven axles shall be measured with one of the following measurement systems:

a. Hub torque meter

b. Rim torque meter

c. Half shaft torque meter

▼M3

3.4.1.2. The following system requirements shall be met by a single torque meter by calibration:

(i) Non linearity:	< ± 6 Nm for heavy lorries and heavy buses
	< ± 5 Nm for medium lorries;
(ii) Repeatability:	< ± 6 Nm for heavy lorries and heavy buses
	< ± 5 Nm for medium lorries;
(iii) Crosstalk:	< ± 10 Nm for heavy lorries and heavy buses
	< ± 8 Nm for medium lorries
	(only applicable for rim torque meters);
(iv) Measurement rate:	≥ 20 Hz

where:

'Non linearity' means the maximum deviation between ideal and actual output signal characteristics in relation to the measurand in a specific measuring range.

'Repeatability' means closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement.

▼M3

'Crosstalk' means signal at the main output of a sensor (M_y), produced by a measurand (F_z) acting on the sensor, which is different from the measurand assigned to this output. Coordinate system assignment is defined in accordance with ISO 4130.

The recorded torque data shall be corrected for the instrument error determined by the supplier.

▼B

3.4.2. Vehicle speed

The vehicle speed is determined by the air drag pre-processing tool based on the CAN-bus front axle signal which is calibrated based on either:

Option (a) : a reference speed calculated by a delta-time from two fixed opto-electronic barriers (see 3.4.4 of this Annex) and the known length(s) of the measurement section(s) or

Option (b) : a delta-time determined speed signal from the position signal of a DGPS and the known length(s) of the measurement section(s), derived by the DGPS coordinates

For the vehicle speed calibration the data recorded during the high speed test are used.

▼M3

3.4.3. Reference signal for calculation of rotational speed of the wheels at the driven axle

One out of three options shall be selected:

Option 1: Engine speed based

The CAN engine speed signal together with the transmission ratios (gears for low speed test and high speed test, axle ratio) shall be made available. For the CAN engine speed signal it shall be demonstrated that the signal provided to the air drag pre-processing tool is identical to the signal to be used for in-service testing as set out in Annex I to Regulation (EU) 582/2011.

For vehicles with torque converter which are not able to drive the low speed test with closed lockup clutch in option 1, additionally the cardan shaft speed signal and the axle ratio or the average wheel speed signal for the driven axle shall be provided to the air drag pre-processing tool. It shall be demonstrated that the engine speed calculated from this additional signal is within 1 % range compared to the CAN engine speed. This shall be demonstrated for the average value over a measurement section driven at the lowest possible vehicle speed in the torque converter locked mode and at the applicable vehicle speed for the high speed test.

Option 2: Wheel speed based

The average of the CAN signals for the rotational speed of left and right wheel at the driven axle shall be made available. Alternatively external sensors may be used. Any method shall fulfill the requirements set out in Table 2 of Annex Xa.

▼M3

Following option 2 the input parameters for gear ratios and axle ratio shall be set to 1, independent of the powertrain configuration.

Option 3: Electric motor speed based

In the case of hybrid and fully electric vehicles, the CAN electric motor speed signal together with the transmission ratios (gears for low speed test and high speed test and if applicable axle ratio) shall be made available. It shall be demonstrated that the wheel speed of the driven axle in the low and high speed test is defined solely by these powertrain configuration specifications.

▼B

3.4.4. Opto-electronic barriers

The signal of the barriers shall be made available to the air drag pre-processing tool for triggering begin and end of the measurement section and the calibration of the vehicle speed signal. The measurement rate of the trigger signal shall be greater or equal to 100 Hz. Alternatively a DGPS system can be used.

3.4.5. (D)GPS system

Option a) for position measurement only: GPS

Required accuracy:

i.	Position :	< 3 m 95 % Circular Error Probable
ii.	Update rate :	≥ 4 Hz

Option b) for vehicle speed calibration and position measurement: Differential GPS system (DGPS)

Required accuracy:

i.	Position :	0,15 m 95 % Circular Error Probable
ii.	Update rate :	≥ 100 Hz

3.4.6. Stationary weather station

Ambient pressure and humidity of the ambient air are determined from a stationary weather station. This meteorological instrumentation shall be positioned in a distance less than 2 000 m to one of the measurement areas, and shall be positioned at an altitude exceeding or equal that of the measurement areas.

Required accuracy:

i.	Temperature :	± 1 °C
ii.	Humidity :	± 5 % RH
iii.	Pressure :	± 1 mbar
iv.	Update rate :	≤ 6 minutes

3.4.7. Mobile anemometer

A mobile anemometer shall be used to measure air flow conditions, i.e. air flow velocity and yaw angle (β) between total air flow and vehicle longitudinal axis.

▼B

3.4.7.1. Accuracy requirements

The anemometer shall be calibrated in facility according to ISO 16622. The accuracy requirements according to Table 1 have to be fulfilled:

Table 1

Anemometer accuracy requirements

Air speed range [m/s]	Accuracy air speed [m/s]	Accuracy yaw angle in yaw angle range of 180 ± 7 degrees [degrees]
20 ± 1	± 0,7	± 1,0
27 ± 1	± 0,9	± 1,0
35 ± 1	± 1,2	± 1,0

▼M3

3.4.7.2. Installation position

The mobile anemometer shall be installed on the vehicle in the prescribed position:

(i) X position:

Medium and heavy rigid lorries and tractors: front face ± 0,3 m of the semi-trailer or box-body;

Heavy buses: Between the end of the front quarter of the vehicle and the rear end of the vehicle.

Medium van lorries: between B-Pillar up to the rear end of the vehicle.

(ii) Y position: plane of symmetry within a tolerance ± 0,1 m;

(iii) Z position:

The installation height above the vehicle shall be one third of the total vehicle height measured from the ground within a tolerance of 0,0 m to + 0,2 m For vehicles with a total vehicle height above 4 m, on request of the manufacturer the installation height above the vehicle can be limited to 1,3 m, with a tolerance of 0,0 m to + 0,2 m.

The instrumentation shall be done as accurate as possible using geometrical or optical aids. Any remaining misalignment is subject to the misalignment calibration to be performed in accordance with 3.6 of this Annex.

▼B

3.4.7.3. The update rate of the anemometer shall be 4 Hz or higher.

3.4.8. Temperature transducer for ambient temperature on vehicle

The ambient air temperature shall be measured on the pole of the mobile anemometer. The installation height shall be maximum 600 mm below the mobile anemometer. The sensor shall be shielded to the sun.

Required accuracy: ± 1 °C

Update rate: ≥ 1 Hz

▼B

3.4.9. Proving ground temperature

The temperature of the proving ground shall be recorded on vehicle by means of a contactless IR sensor by wideband (8 to 14 μm). For tarmac and concrete an emissivity factor of 0,90 shall be used. ►M3 The IR sensor shall be calibrated in accordance with ASTM E2847 or VDI/VDE 3511. ◄

Required accuracy at calibration: Temperature: ± 2,5 °C

Update rate: ≥ 1 Hz

3.5. Constant speed test procedure

On each applicable combination of measurement section and driving direction the constant speed test procedure consisting of the low speed, high speed and low speed test sequence as specified below shall be performed in the same direction.

3.5.1. The average speed within a measurement section in the low speed test shall be a in the range of 10 to 15 km/h.

3.5.2. The average speed within a measurement section in the high speed test shall be in the following range:

▼M3

maximum speed: 95 km/h for medium and heavy lorries and 103 km/h for heavy buses;

▼B

minimum speed: 85 km/h or 3 km/h less than the maximum vehicle speed the vehicle can be operated at the test track, whichever value is lower.

3.5.3. The testing shall be performed strictly according to the sequence as specified in 3.5.3.1 to 3.5.3.9 of this Annex.

3.5.3.1. Preparation of vehicle and measurement systems

(i) Installation of torque meters on the driven axles of the test vehicle and check of installation and signal data according to the manufacturer specification.

(ii) Documentation of relevant general vehicle data for the official testing template in accordance with 3.7 of this Annex.

(iii) For the calculation of the acceleration correction by the air drag pre-processing tool the actual vehicle weight shall be determined before the test within a range of ± 500 kg.

(iv) Check of tyres for the maximum allowable inflation pressure and documentation of tyre pressure values.

(v) Preparation of opto-electronic barriers at the measurement section(s) or check of proper function of the DGPS system.

(vi) Installation of mobile anemometer on the vehicle and/or control of the installation, position and orientation. ►M3 A misalignment calibration test has to be performed every time the anemometer has been mounted newly on the vehicle or has been adjusted. ◄

▼M3

(vii) Check of vehicle setup regarding the height and geometry, in standard ride height position:

▼M3

— Medium and heavy rigid lorries and tractors: the maximum height of the vehicle shall be determined by measuring at the four corners of the box body/semi-trailer.

— Heavy buses and medium van lorries: the maximum height of the vehicle shall be measured in accordance with the technical requirements of Annex I to Regulation (EU) No 1230/2012, by not taking into account the devices and equipment referred to in Appendix 1 of that Annex.

▼B

(viii) Adjustment the height of the semi-trailer to the target value and redo determination of maximum vehicle height if necessary.

(ix) Mirrors or optical systems, roof fairing or other aerodynamic devices shall be in their regular driving condition.

3.5.3.2. Warm-up phase

Drive the vehicle minimum 90 minutes at the target speed of the high speed test to warm-up the system. A repeated warm up (e.g. after a configuration change, an invalid test etc.) shall be at least as long as the standstill time. The warm-up phase can be used to perform the misalignment calibration test as specified in 3.6 of this Annex.

▼M1

In case it is not possible to maintain high speed for a complete round, e.g. due to curves being too narrow, it is allowed to deviate from target speed requirement during the curves, including the nearby straight portions that are needed for slowing down and accelerating the vehicle.

Deviations shall be minimized as far as possible.

Alternatively, the warm-up phase may be performed on a nearby road, if the target speed is maintained within ± 10 km/h for 90 % of the warm-up time. The part of the warm-up phase used for driving from the road to the standstill area of the test track for zeroing of the torque meters shall be included in the other warm-up phase set out in point 3.5.3.4. The time for this part shall not exceed 20 minutes. The speed and time during the warm-up phase shall be recorded by the measurement equipment.

▼B

3.5.3.3. Zeroing of torque meters

The zeroing of the torque meters shall be performed as follows:

i. Bring the vehicle to a standstill

ii. Lift the instrumented wheels off the ground

iii. Perform the zeroing of the amplifier reading of the torque meters

▼M3

The standstill phase shall not exceed 15 minutes.

▼M1

3.5.3.4. Drive another warm-up phase of minimum 10 minutes plus, if applicable, the driving from the road to the standstill area of the test track for zeroing of the torque meters at the target speed of the high speed test. ►M3 The warm-up phase in accordance with this point shall not be shorter than the standstill phase and not exceed 30 minutes. ◄

▼B

3.5.3.5. First low speed test

Perform the first measurement at low speed. It shall be ensured that:

i. the vehicle is driven through the measurement section along a straight line as straight as possible

ii. the average driving speed is in accordance with 3.5.1 of this Annex for the measurement section and the preceding stabilisation section

iii. the stability of the driving speed inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item vii. of this Annex

iv. the stability of the measured torque inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item viii. of this Annex

v. the beginning and the end of the measurement sections are clearly recognizable in the measurement data via a recorded trigger signal (opto-electronic barriers plus recorded GPS data) or via use of a DGPS system

vi. driving at the parts of the test track outside the measurement sections and the preceding stabilisation sections shall be performed without any delay. Any unnecessary manoeuvres shall be avoided during these phases (e.g. driving in sinuous lines)

vii. the maximum time for the low speed test shall not exceed 20 minutes in order to prevent cool down of the tires

▼M3

viii. Any deceleration prior to the start of the low speed test shall be performed in a manner that minimises the use of the mechanical service brake, i.e. by coasting or using the retarder.

▼B

3.5.3.6. Drive another warm-up phase of minimum 5 minutes at the target speed of the high speed test.

3.5.3.7. High speed test

Perform the measurement at the high speed. It shall be ensured that:

i. the vehicle is driven through the measurement section along a straight line as straight as possible

ii. the average driving speed is in accordance with 3.5.2 of this Annex for the measurement section and the preceding stabilisation section

iii. the stability of the driving speed inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item vii. of this Annex

iv. the stability of the measured torque inside the measurement sections and the stabilisation sections is in accordance with 3.10.1.1 item viii. of this Annex

v. the beginning and the end of the measurement sections are clearly recognizable in the measurement data via a recorded trigger signal (opto-electronic barriers plus recorded GPS data) or via use of a DGPS system

▼B

vi. in the driving phases outside the measurement sections and the preceding stabilization sections any unnecessary manoeuvres shall be avoided (e.g. driving in sinuous lines, unnecessary accelerations or decelerations)

vii. the distance between the measured vehicle to another driven vehicle on the test track shall be at least 500 m.

viii. at least 10 valid passings per heading are recorded

The high speed test can be used to determine the misalignment of the anemometer if the provisions stated in 3.6 are fulfilled.

3.5.3.8. Second low speed test

Perform the second measurement at the low speed directly after the high speed test. Similar provisions as for the first low speed test shall be fulfilled.

3.5.3.9. Drift check of torque meters

Directly after the finalisation of the second low speed test the drift check of the torque meters shall be performed in accordance to the following procedure:

1. Bring the vehicle to standstill

2. Lift the instrumented wheels off the ground

3. The drift of each torque meter calculated from the average of the minimum sequence of 10 seconds shall be less than 25 Nm.

Exceeding this limit leads to an invalid test.

3.6. Misalignment calibration test

The misalignment of the anemometer shall be determined by a misalignment calibration test on the test track.

3.6.1. At least 5 valid passings of a 250 ± 3 m straight section driven in each direction at high vehicle speed shall be performed.

3.6.2. The validity criteria for wind conditions as specified in section 3.2.5 of this Annex and the test track criteria as specified in section 3.1 of this Annex are applicable.

3.6.3. The data recorded during the misalignment calibration test shall be used by the air drag pre-processing tool to calculate the misalignment error and perform the according correction. ►M3 The signals for wheel torques and engine, cardan or average wheel speed are not used in the evaluation. ◄

▼B

3.6.4. The misalignment calibration test can be performed independently from the constant speed test procedure. If the misalignment calibration test is performed separately it shall be executed as follows:

i. Prepare the opto-electronic barriers at the 250 m ± 3 m section, or check the proper function of the DGPS System.

ii. Check the vehicle setup regarding the height and geometry in accordance with 3.5.3.1 of this Annex. Adjust the height of the semi-trailer to the requirements as specified in appendix 4 to this Annex if necessary

iii. No prescriptions for warm-up are applicable

iv Perform the misalignment calibration test by at least 5 valid passings as described above.

3.6.5. A new misalignment test shall be performed in the following cases:

a. the anemometer has been dismounted from the vehicle

b. the anemometer has been moved

▼M3

c. a different tractor or rigid lorry is used

▼M1

d. the air drag family has been changed

▼B

3.7. Testing Template

In addition to the recording of the modal measurement data, the testing shall be documented in a template which contains at least the following data:

i. General vehicle description (specifications see Appendix 2 - Information Document)

ii. Actual maximum vehicle height as determined according to 3.5.3.1 item vii.

iii. Start time and date of the test

iv. Vehicle mass within a range of ± 500 kg

v. Tyre pressures

vi. Filenames of measurement data

vii. Documentation of extraordinary events (with time and number of measurement sections), e.g.

— close passing of another vehicle

— manoeuvres to avoid accidents, driving errors

— technical errors

— measurement errors

▼B

3.8. Data processing

3.8.1. The recorded data shall be synchronised and aligned to 100 Hz temporal resolution, either by arithmetical average, nearest neighbour or linear interpolation.

3.8.2. All recorded data shall be checked for any errors. Measurement data shall be excluded from further consideration in the following cases:

— Datasets became invalid due to events during the measurement (see 3.7 item vii)

— Instrument saturation during the measurement sections (e.g. high wind gusts which might have led to anemometer signal saturation)

— Measurements in which the permitted limits for the torque meter drift were exceeded

3.8.3. For the evaluation of the constant speed tests the application of the latest available version of the air drag pre-processing tool shall be obligatory. Besides the above mentioned data processing, all evaluation steps including validity checks (with exception of the list as specified above) are performed by the air drag pre-processing tool.

3.9. ►M1 Input data for air drag pre-processing tool ◄

The following tables show the requirements for the measurement data recording and the preparatory data processing for the input into the air drag pre-processing tool:

Table 2 for the vehicle data file

Table 3 for the ambient conditions file

Table 4 for the measurement section configuration file

Table 5 for the measurement data file

Table 6 for the altitude profile files (optional input data)

►M1 A detailed description of the requested data formats, the input files and the evaluation principles can be found in the technical documentation of the air drag pre-processing tool. ◄ The data processing shall be applied as specified in section 3.8 of this Annex.

▼M3

Table 1

Input data for the air drag pre-processing tool – vehicle data file

Input data	Unit	Remarks
Vehicle group code	[-]	1 – 19 for heavy lorries in accordance with Table 1 of Annex I 31a – 40f for heavy buses in accordance with Tables 4 to 6 of Annex I 51 – 56 for medium lorries in accordance with Table 2 of Annex I
Vehicle configuration with trailer	[-]	if the vehicle was measured without trailer (input ‘No’) or with trailer i.e. as a tractor semitrailer combination (input ‘Yes’)
Vehicle test mass	[kg]	actual mass during measurements

▼M3

Input data	Unit	Remarks
Technically permissible maximum laden mass	[kg]	heavy lorries: technically permissible maximum laden mass of the rigid lorry or tractor (w/o trailer or semitrailer) all other vehicle classes: no entry
Axle ratio	[-]	axle transmission ratio (1) (2)
Gear ratio high speed	[-]	transmission ratio of gear engaged during high speed test (1) (4)
Gear ratio low speed	[-]	transmission ratio of gear engaged during low speed test (1) (4)
Anemometer height	[m]	height above ground of the measurement point of installed anemometer
Vehicle height	[m]	Medium and heavy rigid lorries and tractors: maximum vehicle height in accordance with 3.5.3.1 item vii. all other vehicle classes: no entry
Fixed transmission ratio in low speed test	[-]	'yes' / 'no' (for vehicles which cannot drive with locked torque converter in the low speed test)
Vehicle maximum speed	[km/h]	maximum speed the vehicle can be practically operated at the test track (3)
Torque meter drift left wheel	[Nm]	Average torque meter readings in accordance with point 3.5.3.9.
Torque meter drift right wheel	[Nm]	
Time stamp zeroing of torque meters	[s] since day start (of first day)	
Time stamp drift check torque meters		

(1) specification of transmission ratios with at least 3 digits after decimal separator
(2) if either the cardan speed signal or the average wheel speed signal is provided to the air drag pre-processing tool (see point 3.4.3; option 1 for vehicles with torque converters or option 2) the input parameter on axle ratio shall be set to '1 000'
(3) input only required if value is lower than 88 km/h
(4) if the average wheel speed is provided to the air drag pre-processing tool (see point 3.4.3 option 2) the input parameters on gear ratios shall be set to '1 000'

▼B

Table 3

Input data for the air drag pre-processing tool – ambient conditions file

Signal	Column identifier in input file	Unit	Measurement rate	Remarks
Time	<t>	[s] since day start (first day)	—	—
Ambient temperature	<t_amb_stat>	[°C]	At least 1 averaged value per 6 minutes	Stationary weather station
Ambient pressure	<p_amb_stat>	[mbar]		Stationary weather station
Relative air humidity	<rh_stat>	[%]		Stationary weather station

▼M1

Table 4

Input data for air drag pre-processing tool – measurement section configuration file

▼B

Input data	Unit	Remarks
Trigger signal used	[-]	1 = trigger signal used; 0 = no trigger signal used
Measurement section ID	[-]	user defined ID number
Driving direction ID	[-]	user defined ID number
Heading	[°]	heading of the measurement section
Length of the measurement section	[m]	—
Latitude start point of section	decimal degrees or decimal minutes	standard GPS, unit decimal degrees: minimum 5 digits after decimal separator
Longitude start point of section		standard GPS, unit decimal minutes: minimum 3 digits after decimal separator
Latitude end point of section		DGPS, unit decimal degrees: minimum 7 digits after decimal separator
Longitude end point of section		DGPS, unit decimal minutes: minimum 5 digits after decimal separator
Path and/or filename of altitude file	[-]	only required for the constant speed tests (not the misalignment test) and if the altitude correction is enabled.

Table 5

Input data for the air drag pre-processing tool – measurement data file

Signal	Column identifier in input file	Unit	Measureme-nt rate	Remarks
Time	<t>	[s] since day start (of first day)	100 Hz	rate fixed to 100 Hz; time signal used for correlation with weather data and for check of frequency

▼B

Signal	Column identifier in input file	Unit	Measureme-nt rate	Remarks
(D)GPS latitude	<lat>	decimal degrees or decimal minutes	GPS: ≥ 4 Hz DGPS: ≥ 100 Hz	standard GPS, unit decimal degrees: minimum 5 digits after decimal separator
(D)GPS longitude	<long>			standard GPS, unit decimal minutes: minimum 3 digits after decimal separator DGPS, unit decimal degrees: minimum 7 digits after decimal separator DGPS, unit decimal minutes: minimum 5 digits after decimal separator
(D)GPS heading	<hdg>	[°]	≥ 4Hz	
DGPS velocity	<v_veh_GPS>	[km/h]	≥ 20 Hz	
Vehicle velocity	<v_veh_CAN>	[km/h]	≥ 20 Hz	raw CAN bus front axle signal
Air speed	<v_air>	[m/s]	≥ 4 Hz	raw data (instrument reading)
Inflow angle (beta)	<beta>	[°]	≥ 4 Hz	raw data (instrument reading); '180°' refers to air flow from front

▼M3

Engine speed, cardan speed, average wheel speed or electric motor speed	<n_eng>,<n_c-ard>, <n_wheel_ave> or <n_EM>	[rpm]	≥ 20 Hz	See provisions in point 3.4.3

▼B

Torque meter (left wheel)	<tq_l>	[Nm]	≥ 20 Hz	—
Torque meter (right wheel)	<tq_r>	[Nm]	≥ 20 Hz	
Ambient temperature on vehicle	<t_amb_veh>	[°C]	≥ 1 Hz	
Trigger signal	<trigger>	[-]	100 Hz	optional signal; required if measurement sections are identified by opto elec-tronic barriers (option 'trigger_used=1')
Proving ground temperature	<t_ground>	[°C]	≥ 1 Hz	
Validity	<valid>	[-]	—	optional signal (1=valid; 0=in-valid);

▼B

Table 6

Input data for the air drag pre-processing tool – altitude profile file

Input data	Unit	Remarks
Latitude	decimal degrees or decimal minutes	unit decimal degrees: minimum 7 digits after decimal separator
Longitude		unit decimal minutes: minimum 5 digits after decimal separator
Altitude	[m]	minimum 2 digits after decimal separator

3.10. Validity criteria

This sections sets out the criteria to obtain valid results in the air drag pre-processing tool.

3.10.1. Validity criteria for the constant speed test

3.10.1.1. The air drag pre-processing tool accepts datasets as recorded during the constant speed test in case the following validity criteria are met:

i. the average vehicle speed is inside the criteria as defined in 3.5.2

ii. the ambient temperature is inside the range as described in 3.2.2. This criterion is checked by the air drag pre-processing tool based on the ambient temperature measured on the vehicle.

iii. the proving ground temperature is in the range as described in 3.2.3

iv. valid average wind speed conditions according to point 3.2.5 item i

v. valid gust wind speed conditions according to point 3.2.5 item ii

vi. valid average yaw angle conditions according to point 3.2.5 item iii

vii. stability criteria for vehicle speed met:

Low speed test:

$$(v_{lms,avrg} - 0{,}5\ km/h) \leq v_{lm,avrg} \leq (v_{lms,avrg} + 0{,}5\ km/h)$$

where:

$v_{lms,avrg}$ = average of vehicle speed per measurement section [km/h]

$v_{lm,avrg}$ = central moving average of vehicle speed with X_{ms} seconds time base [km/h]

X_{ms} = time needed to drive 25 m distance at actual vehicle speed [s]

▼B

High speed test:

$$(v_{hms,avrg} - 0{,}3\ km/h) \leq v_{hm,avrg} \leq (v_{hms,avrg} + 0{,}3\ km/h)$$

where:

$v_{hms,avrg}$ = average of vehicle speed per measurement section [km/h]

$v_{hm,avrg}$ = 1 s central moving average of vehicle speed [km/h]

viii. stability criteria for vehicle torque met:

▼M3

Low speed test:

$$(T_{lms,avrg} - T_{grd}) \times (1 - \text{tol}) \leq (T_{lms,avrg} - T_{grd}) \leq (T_{lms,avrg} - T_{grd}) \times (1 + \text{tol})$$

$$T_{grd} = F_{grd,avrg} \times r_{dyn,avrg}$$

where:

$T_{lms,avrg}$ = average of T_{sum} per measurement section

T_{grd} = average torque from gradient force

$F_{grd,avrg}$ = average gradient force over measurement section

$r_{dyn,avrg}$ = average effective rolling radius over measurement section (formula see item xi) [m]

T_{sum} = $T_L + T_R$; sum of corrected torque values left and right wheel [Nm]

$T_{lm,avrg}$ = central moving average of T_{sum} with X_{ms} seconds time base

X_{ms} = time needed to drive 25 m distance at actual vehicle speed [s]

tol = relative torque tolerance: 0.5 for medium lorries and heavy lorries in groups 1s, 1 and 2; 0.3 for heavy lorries in other groups and heavy buses

▼B

High speed test

$$(T_{hms,avrg} - T_{grd}) \times 0{,}8 \leq (T_{hm,avrg} - T_{grd}) \leq (T_{hms,avrg} - T_{grd}) \times 1{,}2$$

where:

$T_{hms,avrg}$ = average of T_{sum} per measurement section [Nm]

T_{grd} = average torque from gradient force (see Low speed test) [Nm]

T_{sum} = T_L+T_R; sum of corrected torque values left and right wheel [Nm]

$T_{hm,avrg}$ = 1 s central moving average of T_{sum} [Nm]

ix. valid heading of the vehicle passing a measurement section (< 10° deviation from target heading applicable for low speed test, high speed test and misalignment test)

x. driven distance inside measurement section calculated from the calibrated vehicle speed does not differ from target distance by more than 3 meters (applicable for low speed test and high speed test)

▼**M1**

xi. ►**M3** plausibility check for engine speed, cardan speed or average wheel speed, whichever is applicable passed: ◄

►**M3** engine speed or average wheel speed ◄ check for high speed test:

$$\frac{30 \cdot i_{gear} \cdot i_{axle} \cdot \frac{(v_{hms,avrg} - 0{,}3)}{3{,}6}}{r_{dyn,ref,HS} \cdot \pi} \cdot (1 - 0{,}02) \leq n_{eng,1s} \leq \frac{30 \cdot i_{gear} \cdot i_{axle} \cdot \frac{(v_{hms,avrg} + 0{,}3)}{3{,}6}}{r_{dyn,ref,HS} \cdot \pi} \cdot (1 + 0{,}02)$$

$$r_{dyn,avrg} = \frac{30 \cdot i_{gear} \cdot i_{axle} \cdot \frac{v_{hms,avrg}}{3{,}6}}{n_{eng,avrg} \cdot \pi}$$

$$r_{dyn,ref,HS} = \frac{1}{n} \sum_{j=1}^{n} r_{dyn,avrg,j}$$

where:

i_{gear}	=	transmission ratio of the gear selected in high speed test [-]
i_{axle}	=	axle transmission ratio [-]
$v_{hms,avrg}$	=	average vehicle speed (high speed measurement section) [km/h]
$n_{eng,1s}$	=	1 s central moving average of ►**M3** engine speed or average wheel speed ◄ (high speed measurement section) [rpm]
$n_{eng,avrg}$	=	average ►**M3** engine speed or average wheel speed ◄ (high speed measurement section) [rpm]
$r_{dyn,avrg}$	=	average effective rolling radius for a single high speed measurement section [m]
$r_{dyn,ref,HS}$	=	reference effective rolling radius calculated from all valid high speed measurement sections (number = n) [m]

►**M3** engine speed or average wheel speed ◄ check for low speed test:

$$\frac{30 \cdot i_{gear} \cdot i_{axle} \cdot \frac{(v_{lms,avrg} - 0{,}5)}{3{,}6}}{r_{dyn,ref,LS1/LS2} \cdot \pi} \cdot (1 - 0{,}02) \leq n_{eng,float} \leq \frac{30 \cdot i_{gear} \cdot i_{axle} \cdot \frac{(v_{lms,avrg} + 0{,}5)}{3{,}6}}{r_{dyn,ref,LS1/LS2} \cdot \pi} \cdot (1 + 0{,}02)$$

$$r_{dyn,avrg} = \frac{30 \cdot i_{gear} \cdot i_{axle} \cdot \frac{v_{lms,avrg}}{3{,}6}}{n_{eng,avrg} \cdot \pi}$$

$$r_{dyn,ref,LS1/LS2} = \frac{1}{n} \sum_{j=1}^{n} r_{dyn,avrg,j}$$

where:

▼M1

i_{gear} = transmission ratio of the gear selected in low speed test [-]

i_{axle} = axle transmission ratio [-]

$v_{lms,avrg}$ = average vehicle speed (low speed measurement section) [km/h]

$n_{eng,float}$ = central moving average of ►M3 engine speed or average wheel speed ◄ with X_{ms} seconds time base (low speed measurement section) [rpm]

$n_{eng,avrg}$ = average ►M3 engine speed or average wheel speed ◄ (low speed measurement section) [rpm]

X_{ms} = time needed to drive 25 metre distance at low speed [s]

$r_{dyn,avrg}$ = average effective rolling radius for a single low speed measurement section [m]

$r_{dyn,ref,LS1/LS2}$ = reference effective rolling radius calculated from all valid measurement sections for low speed test 1 or low speed test 2 (number = n) [m]

The plausibility check for cardan speed is performed in an analogue way with $n_{eng,1s}$ replaced by $n_{card,1s}$ (1 s central moving average of cardan speed in the high speed measurement section) and $n_{eng,float}$ replaced by $n_{card,float}$ (moving average of cardan speed with X_{ms} seconds time base in the low speed measurement section) and i_{gear} set to a value of 1.

▼B

xii. the particular part of the measurement data was not marked as ‘invalid’ in the air drag pre-processing tool input file.

3.10.1.2. The air drag pre-processing tool excludes single datasets from the evaluation in the case of unequal number of datasets for a particular combination of measurement section and driving direction for the first and the second low speed test. In this case the first datasets from the low speed run with the higher number of datasets are excluded.

3.10.1.3. The air drag pre-processing tool excludes single combinations of measurement sections and driving directions from the evaluation if:

i. no valid dataset is available from low speed test 1 or/and low speed test 2

ii. less than two valid datasets from the high speed test are available

3.10.1.4. The air drag pre-processing tool considers the complete constant speed test invalid in the following cases:

i. test track requirements as described in 3.1.1 not met

ii. less than 10 datasets per heading available (high speed test)

iii. less than 5 valid datasets per heading available (misalignment calibration test)

▼B

iv. the rolling resistance coefficients (RRC) for the first and the second low speed test differ more than 0,40 kg/t. This criterion is checked for each combination of measurement section and driving direction separately.

3.10.2. Validity criteria for the misalignment test

3.10.2.1. The air drag pre-processing tool accepts datasets as recorded during the misalignment test in case the following validity criteria are met:

i. the average vehicle speed is inside the criteria as defined in 3.5.2 for the high speed test

ii. valid average wind speed conditions according to point 3.2.5 item i

iii. valid gust wind speed conditions according to point 3.2.5 item ii

iv. valid average yaw angle conditions according to point 3.2.5 item iii

v. stability criteria for vehicle speed met:

$$(v_{hms,avrg} - 1\ km/h) \leq v_{hm,avrg} \leq (v_{hms,avrg} + 1\ km/h)$$

where:

$v_{hms,avrg}$ = average of vehicle speed per measurement section [km/h]

$v_{hm,avrg}$ = 1 s central moving average of vehicle speed [km/h]

3.10.2.2. The air drag pre-processing tool considers the data from a single measurement section invalid in the following cases:

i. the average vehicle speeds from all valid datasets from each driving directions differ by more than 2 km/h.

ii. less than 5 datasets per heading available

3.10.2.3. The air drag pre-processing tool considers the complete misalignment test invalid in case no valid result for a single measurement section is available.

3.11. Declaration of air drag value

Base value for the declaration of the air drag value is the final result for $C_d \cdot A_{cr}\ (0)$ as calculated by the air drag pre-processing tool. The applicant for a certificate shall declare a value $C_d \cdot A_{declared}$ in a range from equal up to a maximum of + 0,2 m^2 higher than $C_d \cdot A_{cr}\ (0)$. This tolerance shall take into account uncertainties in the selection of the parent vehicles as the worst case for all testable members of the family. The value $C_d \cdot A_{declared}$ shall be the input for the simulation tool and the reference value for conformity of the certified CO_2 emissions and fuel consumption related properties testing.

▼M3

Several declared values $C_d{\cdot}A_{declared}$ can be created based on a single measured $C_d{\cdot}A_{cr}\ (0)$ as long as the family provisions in accordance with point 3.1 of Appendix 5 for medium and heavy lorries and with point 4.1 of Appendix 5 for heavy buses are fulfilled.

▼B

Appendix 1

MODEL OF A CERTIFICATE OF A COMPONENT, SEPARATE TECHNICAL UNIT OR SYSTEM

Maximum format: A4 (210 × 297 mm)

CERTIFICATE ON CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF AN AIR DRAG FAMILY

Communication concerning:	Administration stamp

— granting (1)

— extension (1)

— refusal (1)

— withdrawal (1)

of a certificate on CO_2 emission and fuel consumption related properties of an air drag family in accordance with Commission Regulation (EU) 2017/2400.

Commission Regulation (EU) 2017/2400 as last amended by ....

Certification number:

Hash:

Reason for extension:

SECTION I

0.1. Make (trade name of manufacturer):

0.2. Vehicle body and air drag type/family (if applicable):

0.3. Vehicle body and air drag family member (in case of family)

0.3.1. Vehicle body and air drag parent

0.3.2. Vehicle body and air drag types within the family

0.4. Means of identification of type, if marked

0.4.1. Location of the marking:

0.5. Name and address of manufacturer:

0.6. In the case of components and separate technical units, location and method of affixing of the EC certification mark:

0.7. Name(s) and address(es) of assembly plant(s):

0.9. Name and address of the manufacturer's representative (if any)

SECTION II

1. Additional information (where applicable): see Addendum

2. Approval authority responsible for carrying out the tests:

3. Date of test report:

4. Number of test report:

5. Remarks (if any): see Addendum

▼**B**

6. Place:

7. Date:

8. Signature:

Attachments:

Information package. Test report.

▼**M1**

Appendix 2

Air drag information document

Description sheet No: Issue:

from:

Amendment:

pursuant to …

Air Drag type or family (if applicable):

General remark: For simulation tool input data an electronic file format needs to be defined which can be used for data import to the simulation tool. The simulation tool input data may differ from the data requested in the information document and vice versa (to be defined). A data file is especially necessary wherever large data such as efficiency maps need to be handled (no manual transfer/input necessary).

…

0.0. GENERAL

0.1. Name and address of manufacturer

0.2. Make (trade name of manufacturer)

0.3. Air drag type (family if applicable)

0.4. Commercial name(s) (if available)

0.5. Means of identification of type, if marked on the vehicle

0.6. In the case of components and separate technical units, location and method of affixing of the certification mark

0.7. Name(s) and address(es) of assembly plant(s)

0.8. Name and address of the manufacturer's representative

▼M1

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) AIR DRAG AND THE AIR DRAG TYPES WITHIN AN AIR DRAG FAMILY

		Parent air drag or air drag type	Family members #1	#2	#3
1.0.	SPECIFIC AIR DRAG INFORMATION				
1.1.0.	VEHICLE				
1.1.1.	HDV group according to HDV CO_2 scheme				
▼M3					
1.2.0.	Vehicle model / Commercial Name				
1.2.1.	Axle configuration				
1.2.2	Technically permissible maximum laden mass				
1.2.3.	Cabin or model line				
1.2.4.	Cabin width (max. value in Y direction, for vehicles with a cabin)				
1.2.5.	Cabin length (max. value in X direction, for vehicles with a cabin)				
1.2.6.	Roof height (for vehicles with a cabin)				
1.2.7.	Wheel base				
1.2.8.	Height cabin over frame (for vehicles with a frame)				
1.2.9.	Frame height (for vehicles with a frame)				
1.2.10.	Aerodynamic accessories or add-ons (e.g. roof spoiler, side extender, side skirts, corner vanes)				
1.2.11.	Tyre dimensions front axle				
1.2.12.	Tyre dimensions driven axles(s)				
1.2.13.	Vehicle width in accordance with item (8) of point 2 of Annex III (for vehicles without a cabin)				
1.2.14.	Vehicle length in accordance with item (7) of point 2 of Annex III (for vehicles without a cabin)				
1.2.15.	Height of the integrated body in accordance with item (5) of point 2 of Annex III (for vehicles without a cabin)				
▼M1					
1.3.	Body specifications (according to standard body definition)				
1.4.	(Semi-) Trailer specifications (according to (semi-) trailer specification by standard body)				
1.5.	Parameter defining the family in accordance with the description of the applicant (parent criteria and deviated family criteria)				

▼**M1**

LIST OF ATTACHMENTS

No:	Description:	Date of issue:
1.	Information on test conditions	…
2.	…	

▼**M1**

Attachment 1 to Information Document

Information on test conditions (if applicable)

1.1. Test track on which tests have been conducted

1.2. Total vehicle mass during measurement [kg]

1.3. Maximum vehicle height during measurement [m]

1.4. Average ambient conditions during first low speed test [°C]

1.5. Average vehicle speed during high speed tests [km/h]

1.6. Product of drag coefficient (C_d) by cross sectional area (A_{cr}) for zero crosswind conditions $C_dA_{cr}(0)$ [m^2]

1.7. Product of drag coefficient (C_d) by cross sectional area (A_{cr}) for average crosswind conditions during constant speed test $C_dA_{cr}(\beta)$ [m^2]

1.8. Average yaw angle during constant speed test β [°]

1.9. Declared air drag value $C_d{\cdot}A_{declared}$ [m^2]

1.10. Version number of air drag pre-processing tool

▼**M3**

Appendix 3

Vehicle height requirements for rigid lorries and tractors

1. Medium rigid lorries, heavy rigid lorries and tractors measured in the constant speed test in accordance with point 3 of this Annex have to meet the vehicle height requirements as shown in Table 2.

2. The vehicle height has to be determined as described in 3.5.3.1, item (vii).

3. Any kind of rigid lorries and tractors of vehicle groups not shown in Table 2 are not subject to constant speed testing.

Table 2

Vehicle height requirements for medium rigid lorries, heavy rigid lorries and tractors

Vehicle group	minimum vehicle height [m]	maximum vehicle height [m]
51, 53, 55	3,20	3,50
1s, 1	3,40	3,60
2	3,50	3,75
3	3,70	3,90
4	3,85	4,00
5	3,90	4,00
9	similar values as for rigid lorries with same technically permissible maximum laden mass (group 1, 2, 3 or 4)	
10	3,90	4,00

▼B

Appendix 4

▼M3

Standard body and semitrailer configurations for rigid lorries and tractors

▼B

1. ►M3 Medium rigid lorries and heavy rigid lorries which are subject to determination of air drag have to fulfil the requirements on standard bodies as described in this Appendix. Tractors have to fulfil the requirements for standard semitrailers as described in this Appendix. ◄

2. The applicable standard body or semitrailer shall be determined from Table 8.

▼M3

Table 3

Allocation of standard bodies and semitrailer for constant speed testing

Vehicle groups	Standard body or trailer
51, 53, 55	B-II
1s, 1	B1
2	B2
3	B3
4	B4
5	ST1
9	depending on technically permissible maximum laden mass: 7,5 – 10 t: B1 > 10 – 12 t: B2 > 12 – 16 t: B3 > 16 t: B5
10	ST1

3. The standard bodies B-II, B1, B2, B3, B4 and B5 shall be constructed as a hard shell body in dry-out box design. They shall be equipped with two rear doors and without any side doors. The standard bodies shall not be equipped with tail lifts, front spoilers or side fairings for reduction of aerodynamic drag. The specifications of the standard bodies are given in:

   Table 9a for standard body 'B-II'

   Table 9 for standard body 'B1'

   Table 10 for standard body 'B2'

   Table 11 for standard body 'B3'

   Table 12 for standard body 'B4'

   Table 13 for standard body 'B5'

   Mass indications as given in Table 9a to Table 15 are not subject to inspection for air drag testing.

▼B

4. The type and chassis requirements for the standard semitrailer ST1 are listed in Table 14. The specifications are given in Table 15.

▼B

5. All dimensions and masses without tolerances mentioned explicitly shall be in line with Regulation (EC) No 1230/2012, Annex 1, Appendix 2 (i.e. in the range of ± 3 % of the target value).

Table 9

Specifications of standard body 'B1'

Specification	Unit	External dimension (tolerance)	Remarks
Length	[mm]	6 200	
Width	[mm]	2 550 (– 10)	
Height	[mm]	2 680 (± 10)	box: external height: 2 560 longitudinal beam: 120
Corner radius side & roof with front panel	[mm]	50 - 80	
Corner radius side with roof panel	[mm]	50 - 80	
Remaining corners	[mm]	broken with radius ≤ 10	
Mass	[kg]	1 600	►M3 Mass is used as a generic value in the simulation tool and does not need to be verified for air drag testing ◄

▼M3

Table 9a

Specifications of standard body 'B-II'

Specification	Unit	External dimension (tolerance)	Remarks
Length	[mm]	4 500 (± 10)	
Width	[mm]	2 300 (± 10)	
Height	[mm]	2 500 (± 10)	box: external height: 2 380 longitudinal beam: 120
Corner radius side & roof with front panel	[mm]	30 - 80	
Corner radius side with roof panel	[mm]	30 - 80	
Remaining corners	[mm]	broken with radius ≤ 10	
Mass	[kg]	800	Mass is used as a generic value in the simulation tool and does not need to be verified for air drag testing

▼**B**

Table 10

Specifications of standard body ‘B2’

Specification	Unit	External dimension (tolerance)	Remarks
Length	[mm]	7 400	
Width	[mm]	2 550 (– 10)	
Height	[mm]	2 760 (± 10)	box: external height: 2 640 longitudinal beam: 120
Corner radius side & roof with front panel	[mm]	50 - 80	
Corner radius side with roof panel	[mm]	50 - 80	
Remaining corners	[mm]	broken with radius ≤ 10	
Mass	[kg]	1 900	►**M3** Mass is used as a generic value in the simulation tool and does not need to be verified for air drag testing ◄

Table 11

Specifications of standard body ‘B3’

Specification	Unit	External dimension (tolerance)	Remarks
Length	[mm]	7 450	
Width	[mm]	2 550 (– 10)	legal limit (96/53/EC), internal ≥ 2 480
Height	[mm]	2 880 (± 10)	box: external height: 2 760 longitudinal beam: 120
Corner radius side & roof with front panel	[mm]	50 - 80	
Corner radius side with roof panel	[mm]	50 - 80	
Remaining corners	[mm]	broken with radius ≤ 10	
Mass	[kg]	2 000	►**M3** Mass is used as a generic value in the simulation tool and does not need to be verified for air drag testing ◄

▼**B**

Table 12

Specifications of standard body 'B4'

Specification	Unit	External dimension (tolerance)	Remarks
Length	[mm]	7 450	
Width	[mm]	2 550 (– 10)	
Height	[mm]	2 980 (± 10)	box: external height: 2 860 longitudinal beam: 120
Corner radius side & roof with front panel	[mm]	50 - 80	
Corner radius side with roof panel	[mm]	50 - 80	
Remaining corners	[mm]	broken with radius ≤ 10	
Mass	[kg]	2 100	►**M3** Mass is used as a generic value in the simulation tool and does not need to be verified for air drag testing ◄

Table 13

Specifications of standard body 'B5'

Specification	Unit	External dimension (tolerance)	Remarks
Length	[mm]	7 820	internal ≥ 7 650
Width	[mm]	2 550 (– 10)	legal limit (96/53/EC), internal ≥ 2 460
Height	[mm]	2 980 (± 10)	box: external height: 2 860 longitudinal beam: 120
Corner radius side & roof with front panel	[mm]	50 - 80	
Corner radius side with roof panel	[mm]	50 - 80	
Remaining corners	[mm]	broken with radius ≤ 10	
Mass	[kg]	2 200	►**M3** Mass is used as a generic value in the simulation tool and does not need to be verified for air drag testing ◄

▼B

Table 14

Type and chassis configuration of standard semitrailer 'ST1'

Type of trailer	3-axle semi-trailer w/o steering axle(s)
Chassis configuration	— End to end ladder frame — Frame w/o underfloor cover — 2 stripes at each side as underride protection — Rear underride protection (UPS) — Rear lamp holder plate — w/o pallet box — Two spare wheels after the 3rd axle — One toolbox at the end of the body before UPS (left or right side) — Mud flaps before and behind axle assembly — Air suspension — Disc brakes — Tyre size: 385/65 R 22,5 — 2 back doors — w/o side door(s) — w/o tail lift — w/o front spoiler — w/o side fairings for aero

Table 15

▼M1

Specifications standard semitrailer 'ST1'

▼B

Specification	Unit	External dimension (tolerance)	Remarks
Total length	[mm]	13 685	
Total width (Body width)	[mm]	2 550 (– 10)	
Body height	[mm]	2 850 (± 10)	max. full height: 4 000 (96/53/EC)
Full height, unloaded	[mm]	4 000 (– 10)	height over the complete length specification for semi-trailer, not relevant for checking of vehicle height during constant speed test
Trailer coupling height, unloaded	[mm]	1 150	specification for semitrailer, not subject to inspection during constant speed test

▼B

Specification	Unit	External dimension (tolerance)	Remarks
Wheelbase	[mm]	7 700	
Axle distance	[mm]	1 310	3-axle assembly, 24t (96/53/EC)
Front overhang	[mm]	1 685	radius: 2 040 (legal limit, 96/53/EC)
Front wall			flat wall with attachments for compressed air and electricity
Corner front/side panel	[mm]	broken with a strip and edge radii ≤ 5	secant of a circle with the kingpin as centre and a radius of 2 040 (legal limit, 96/53/EC)
Remaining corners	[mm]	broken with radius ≤ 10	
Toolbox dimension vehicle x-axis	[mm]	655	Tolerance: ± 10 % of target value
Toolbox dimension vehicle y-axis	[mm]	445	Tolerance: ± 5 % of target value
Toolbox dimension vehicle z-axis	[mm]	495	Tolerance: ± 5 % of target value
Side underride protection length	[mm]	3 045	2 stripes at each side, acc. ECE-R 73, Amendment 01 (2010), +/– 100 depending on wheelbase
Stripe profile	[mm^2]	100 × 30	ECE- R 73, Amendment 01 (2010)
Technical gross vehicle weight	[kg]	39 000	legal GVWR: 24 000 (96/53/EC)
Vehicle curb weight	[kg]	7 500	has not be verified during air drag testing
Allowable axle load	[kg]	24 000	legal limit (96/53/EC)
Technical axle load	[kg]	27 000	3 × 9 000

▼B

Appendix 5

▼M3

Air drag family

▼B

1. General

An air drag family is characterized by design and performance parameters. These shall be common to all vehicles within the family. ►M3 The manufacturer may decide which vehicles belong to an air drag family as long as the membership criteria listed in point 3 for medium lorries, heavy lorries and point 6 for heavy buses are respected. ◄ The air drag family shall be approved by the approval authority. The manufacturer shall provide to the approval authority the appropriate information relating to the air drag of the members of the air drag family.

2. Special cases

In some cases there may be interaction between parameters. This shall be taken into consideration to ensure that only vehicles with similar characteristics are included within the same air drag family. These cases shall be identified by the manufacturer and notified to the approval authority. It shall then be taken into account as a criterion for creating a new air drag family.

▼M3

In addition to the parameters listed in point 4 of this Appendix for medium and heavy lorries and point 6.1 of this Appendix for heavy buses, the manufacturer may introduce additional criteria allowing the definition of families of more restricted size.

▼M1

————————

▼M3

4. Parameter defining the air drag family for medium and heavy lorries

▼B

4.1. ►M3 Medium and heavy lorries are allowed to be grouped within a family if they belong to the same vehicle group according to Table 1 or Table 2 of Annex I and the following criteria are fulfilled: ◄

(a) Same cabin width and body in white geometry up to B-pillar and above the heel point excluding the cab bottom (e.g. engine tunnel). All members of the family stay within a range of ± 10 mm to the parent vehicle.

(b) Same roof height in vertical Z. All members of the family stay within a range of ± 10 mm to the parent vehicle.

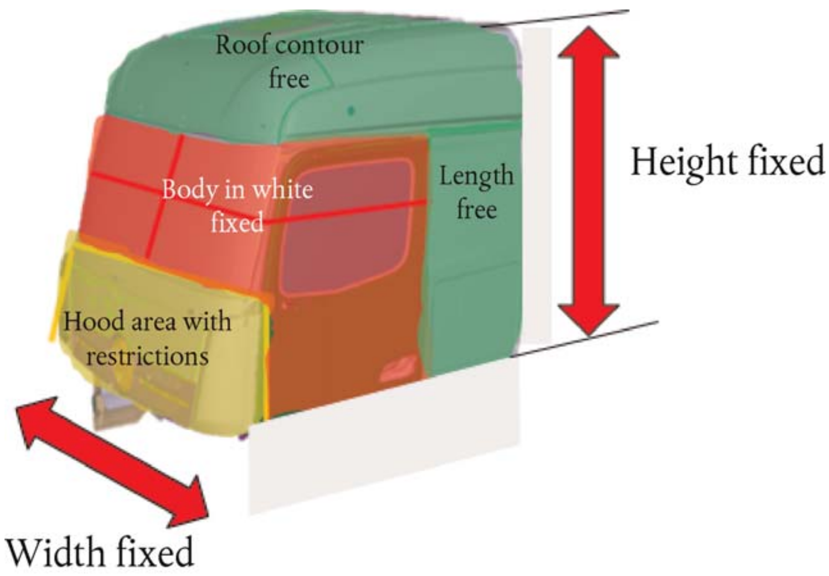
(c) ►M3 For vehicles with frame: Same height of cabin over frame. ◄ This criterion is fulfilled if the height difference of the cabins over frame stays within Z < 175mm.

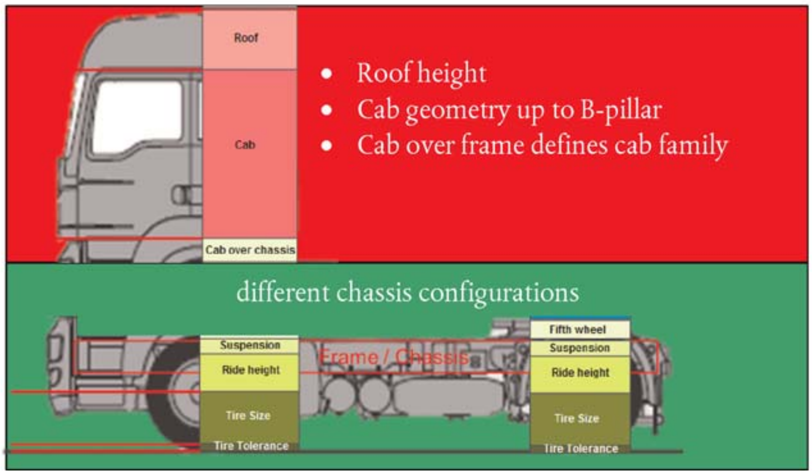
The fulfillment of the family concept requirements shall be demonstrated by CAD (computer-aided design) data.

▼B

Figure 1

Family definition





4.2. An air drag family consist of testable members and vehicle configurations which can not be tested in accordance with this regulation.

4.3. Testable members of a family are vehicle configurations, which fulfil the installation requirements as defined in 3.3 in the main part of this Annex.

▼M3

5. Choice of the air drag parent vehicle for medium and heavy lorries

▼B

5.1. The parent vehicle of each family shall be selected according to the following criteria:

▼M3

5.2. For medium rigid lorries, heavy rigid lorries and tractors the vehicle chassis shall fit to the dimensions of the standard body or semi-trailer as defined in Appendix 4 of this Annex.

▼B

5.3. All testable members of the family shall have an equal or lower air drag value than the value $C_d \cdot A_{declared}$ declared for the parent vehicle.

▼M3

5.4. The applicant for a certificate shall be able to demonstrate that the selection of the parent vehicle meets the provisions as stated in point 5.3. based on scientific methods e.g. computational fluid dynamics (CFD), wind tunnel results or good engineering practice. This provision applies for all vehicle variants which can be tested by the constant speed procedure as described in point 3 of this Annex. Other vehicle configurations (e.g. vehicle heights not in accordance with the provisions in Appendix 4, wheel bases not compatible with the standard body dimensions of Appendix 5) shall get the same air drag value as the testable parent within the family without any further demonstration. As tires are considered as part of the measurement equipment, their influence shall be excluded in proving the worst case scenario.

5.5. For heavy lorries the declared value $C_d \cdot A_{declared}$ can be used for creation of families in other vehicle groups if the family criteria in accordance with point 5 of this Appendix are met based on the provisions given in Table 16.

Table 16

Provisions for transfer of air drag values of heavy lorries to other vehicle groups

Vehicle group	Transfer formula	Remarks
1, 1s	Vehicle group 2 – 0,2 m^2	Only allowed if value for related family in group 2 was measured
2	Vehicle group 3 – 0,2 m^2	Only allowed if value for related family in group 3 was measured
3	Vehicle group 4 – 0,2 m^2	
4	No transfer allowed	
5	No transfer allowed	
9	Vehicle group 1,2,3,4 + 0,1 m^2	Applicable group for transfer has to match with TPMLM (technically permissible maximum laden mass). In the case of a TPMLM of > 16 tons: — group 4 shall be the basis for the transfer for group 9 — group 5 shall be the basis for the transfer for group 10 Transfer of already transferred values allowed.
10	Vehicle group 1,2,3,5 + 0,1 m^2	

▼M3

Vehicle group	Transfer formula	Remarks
11	Vehicle group 9	Transfer of already transferred values allowed
12	Vehicle group 10	Transfer of already transferred values allowed
16	Vehicle group 9 + 0,3 m^2	Transfer to already transferred values allowed

5.6. For medium lorries the declared value $C_d \cdot A_{declared}$ may be transferred for creation of families in other vehicle groups if the family criteria in accordance with point 5 of this Appendix are met and the provisions in Table 16a are fulfilled. The transfer shall be done by taking over the $C_d \cdot A_{declared}$ value unchanged from the origin group.

Table 16a

Provisions for transfer of air drag values of medium lorries to other vehicle groups

Vehicle group	Transfer allowed from vehicle group(s)
51	53
52	54
53	51
54	52

6. Parameter defining the air drag family for heavy buses:

6.1. Heavy buses are allowed to be grouped within a family if they belong to the same vehicle group according to Tables 4, 5 and 6 of Annex I and the following criteria are fulfilled:

(a) Vehicle width: All members of the family stay within a range of ± 50 mm to the parent vehicle. The body width shall be determined in accordance with the definitions as set out in Annex III.

(b) Height of the integrated body: All members of the family shall stay within the total range of 250 mm. The height of the integrated body shall be determined in accordance with the definitions as set out in Annex III.

(c) Vehicle length: All members of the family stay within a total range of 5 m. The length shall be determined in accordance with the definitions as set out in Annex III.

The fulfilment of the family concept requirements shall be demonstrated by computer-aided design data or drawings. The method of demonstration shall be chosen by the manufacturer.

7. Choice of the air drag parent vehicle for heavy buses

The parent vehicle of each family shall be selected in accordance with the following criteria:

▼M3

7.1. All members of the family shall have an equal or lower air drag value than the value $C_d{\cdot}A_{declared}$ for the parent vehicle.

7.2 The applicant for a certificate shall be able to demonstrate that the selection of the parent vehicle meets the provisions as stated in 7.1. based on scientific methods e.g. computational fluid dynamics, wind tunnel results or good engineering practice. This demonstration shall cover the influence of roof mounted systems. As tires are considered as part of the measurement equipment, their influence shall be excluded in proving the worst case scenario.

7.3. The declared value $C_d{\cdot}A_{declared}$ can be used for creation of families in other sub-groups if the family criteria in accordance with point 1 of this Appendix are met, based on transfer functions or provisions in accordance with Table 16b. Multiple combinations of copy and transfer functions are allowed.

For vehicles of sub-groups labelled with "no" in the second column of Table 16b generic values for air drag are allocated automatically by the simulation tool.

Table 16b

Provisions for transfer of air drag values between the vehicle groups

Vehicle parameter sub-group	Air drag measurement allowed	Transfer allowed from vehicle group(s) and transfer formula for $C_d{\cdot}A_{declared}$	Transfer allowed from vehicle group(s) by taking over $C_d{\cdot}A_{declared}$ unchanged from the origin group
31a	no	not applicable	not applicable
31b1	no	not applicable	not applicable
31b2	only for interurban cycle	not applicable	32a, 32b, 32c, 32d, 33b2, 34a, 34b, 34c, 34d
31c	no	not applicable	not applicable
31d	no	not applicable	not applicable
31e	no	not applicable	not applicable
32a	yes	not applicable	31b2, 32b, 32c, 32d, 34a, 34b, 34c, 34d
32b	yes	not applicable	31b2, 32a, 32c, 32d, 34a, 34b, 34c, 34d
32c	yes	not applicable	31b2, 32a, 32b, 32d, 34a, 34b, 34c, 34d
32d	yes	not applicable	31b2, 32a, 32b, 32c, 34a, 34b, 34c, 34d
32e	yes	not applicable	32f, 34e, 34f
32f	yes	not applicable	32e, 34e, 34f
33a	no	not applicable	not applicable
33b1	no	not applicable	not applicable
33b2	only for interurban cycle	vehicle group 31b2 + 0,1 m^2	34a, 34b, 34c, 34d, 35b2, 36a, 36b, 36c, 36d

▼**M3**

Vehicle parameter sub-group	Air drag measurement allowed	Transfer allowed from vehicle group(s) and transfer formula for $C_d{\cdot}A_{declared}$	Transfer allowed from vehicle group(s) by taking over $C_d{\cdot}A_{declared}$ unchanged from the origin group
33c	no	not applicable	not applicable
33d	no	not applicable	not applicable
33e	no	not applicable	not applicable
34a	yes	vehicle group 32a + 0,1 m^2	33b2, 34b, 34c, 34d, 35b2, 36a, 36b, 36c, 36d
34b	yes	vehicle group 32b + 0,1 m^2	33b2, 34a, 34c, 34d, 35b2, 36a, 36b, 36c, 36d
34c	yes	vehicle group 32c + 0,1 m^2	33b2, 34a, 34b, 34d, 35b2, 36a, 36b, 36c, 36d
34d	yes	vehicle group 32d + 0,1 m^2	33b2, 34a, 34b, 34c, 35b2, 36a, 36b, 36c, 36d
34e	yes	vehicle group 32e + 0,1 m^2	34f, 36e, 36f
34f	yes	vehicle group 32f + 0,1 m^2	34e, 36e, 36f
35a	no	not applicable	not applicable
35b1	no	not applicable	not applicable
35b2	only for interurban cycle	vehicle group 33b2 + 0,1 m^2	36a, 36b, 36c, 36d, 37b2, 38a, 38b, 38c, 38d
35c	no	not applicable	not applicable
36a	yes	vehicle group 34a + 0,1 m^2	35b2, 36b, 36c, 36d, 37b2, 38a, 38b, 38c, 38d
36b	yes	vehicle group 34b + 0,1 m^2	35b2, 36a, 36c, 36d, 37b2, 38a, 38b, 38c, 38d
36c	yes	vehicle group 34c + 0,1 m^2	35b2, 36a, 36b, 36d, 37b2, 38a, 38b, 38c, 38d
36d	yes	vehicle group 34d + 0,1 m^2	35b2, 36a, 36b, 36c, 37b2, 38a, 38b, 38c, 38d
36e	yes	vehicle group 34e + 0,1 m^2	36f, 38e, 38f
36f	yes	vehicle group 34f + 0,1 m^2	36e, 38e, 38f
37a	no	not applicable	not applicable
37b1	no	not applicable	not applicable -
37b2	only for interurban cycle	vehicle group 33b2 + 0,1 m^2	38a, 38b, 38c, 38d, 39b2, 40a, 40b, 40c, 40d

▼M3

Vehicle parameter sub-group	Air drag measurement allowed	Transfer allowed from vehicle group(s) and transfer formula for $C_d \cdot A_{declared}$	Transfer allowed from vehicle group(s) by taking over $C_d \cdot A_{declared}$ unchanged from the origin group
37c	no	not applicable	not applicable
37d	no	not applicable	not applicable
37e	no	not applicable	not applicable
38a	yes	vehicle group 34a + 0,1 m^2	37b2, 38b, 38c, 38d, 39b2, 40a, 40b, 40c, 40d
38b	yes	vehicle group 34b + 0,1 m^2	37b2, 38a, 38c, 38d, 39b2, 40a, 40b, 40c, 40d
38c	yes	vehicle group 34c + 0,1 m^2	37b2, 38a, 38b, 38d, 39b2, 40a, 40b, 40c, 40d
38d	yes	vehicle group 34d + 0,1 m^2	37b2, 38a, 38b, 38c, 39b2, 40a, 40b, 40c, 40d
38e	yes	vehicle group 34e + 0,1 m^2	38f, 40e, 40f
38f	yes	vehicle group 34f + 0,1 m^2	38e, 40e, 40f
39a	no	not applicable	not applicable
39b1	no	not applicable	not applicable
39b2	only for interurban cycle	vehicle group 35b2 + 0,1 m^2	40a, 40b, 40c, 40d
39c	no	not applicable	not applicable
40a	yes	vehicle group 36a + 0,1 m^2	39b2, 40b, 40c, 40d
40b	yes	vehicle group 36b + 0,1 m^2	39b2, 40a, 40c, 40d
40c	yes	vehicle group 36c + 0,1 m^2	39b2, 40a, 40b, 40d
40d	yes	vehicle group 36d + 0,1 m^2	39b2, 40a, 40b, 40c
40e	yes	vehicle group 36e + 0,1 m^2	40f
40f	yes	vehicle group 36f + 0,1 m^2	40e

▼B

Appendix 6

Conformity of the certified CO_2 emissions and fuel consumption related properties

1. The conformity of the certified CO_2 emissions and fuel consumption related properties shall be verified by constant speed tests as laid down in section 3 of the main part of this Annex. For conformity of the certified CO_2 emissions and fuel consumption related properties the following additional provisions apply:

   i. The ambient temperature of the constant speed test shall be within a range of ± 5 °C to the value from the certification measurement. This criterion is verified based on the average temperature from the first low speed tests as calculated by the air drag pre-processing tool.

   ii. The high speed test shall be performed in a vehicle speed range within ± 2 km/h to the value from the certification measurement.

   All conformity of the certified CO_2 emissions and fuel consumption related properties tests shall be supervised by the approval authority.

2. A vehicle fails the conformity of the certified CO_2 emissions and fuel consumption related properties test if the measured $C_d\ A_{cr}\ (0)$ value is higher than the $C_d \cdot A_{declared}$ value declared for the parent vehicle plus 7,5 % tolerance margin. If a first test fails, up to two additional tests at different days with the same vehicle may be performed. ►M1 Where the measured $C_d\ A_{cr}\ (0)$ value of all performed tests is higher than the $C_d \cdot A_{declared}$ value declared for the parent vehicle plus 7,5 % tolerance margin, Article 23 of this Regulation shall apply. ◄

▼M1

For calculation of $C_d\ A_{cr}\ (0)$ value the air drag pre-processing tool version of the parent air drag in accordance with Attachment 1 of Appendix 2 to this Annex shall be used.

▼M3

3. The number of vehicles to be tested for conformity with the certified CO_2 emissions and fuel consumption related properties per year of production shall be determined based on Table 17. The table shall be applied separately to medium lorries, heavy lorries and heavy buses.

Table 17

Number of vehicles to be tested for conformity with the certified CO_2 emissions and fuel consumption related properties per year of production

(to be applied separately for medium lorries, heavy lorries and heavy buses)

Number of CoP tested vehicles	Schedule	Number of CoP relevant vehicles produced the year before
0	—	≤ 25
1	every 3rd year (1)	25 < X ≤ 500
1	every 2nd year	500 < X ≤ 5 000
1	every year	5 000 < X ≤ 15 000

▼M3

Number of CoP tested vehicles	Schedule	Number of CoP relevant vehicles produced the year before
2	every year	≤ 25 000
3	every year	≤ 50 000
4	every year	≤ 75 000
5	every year	≤ 100 000
6	every year	100 001 and more

(1) The CoP test shall be performed within the first two years

For the purpose of establishing the production numbers, only air drag data which fall under the requirements of this Regulation and which did not get standard air drag values according to Appendix 7 of this Annex shall be considered.

▼B

4. For the selection of vehicles for conformity of the certified CO_2 emissions and fuel consumption related properties testing the following provisions apply:

4.1. Only vehicles from the production line shall be tested.

4.2. Only vehicles which fulfil the provisions for constant speed testing as laid down in section 3.3 of the main part of this Annex shall be selected.

4.3. Tires are considered part of the measurement equipment and can be selected by the manufacturer.

4.4. Vehicles in families where the air drag value has been determined via transfer from other vehicles according to Appendix 5 point 5 are not subject to conformity of the certified CO_2 emissions and fuel consumption related properties testing.

4.5. Vehicles which use standard values for air drag according to Appendix 8 are not subject to conformity of the certified CO_2 emissions and fuel consumption related properties testing.

▼M3

4.6. A first vehicle to be tested for conformity with the certified CO_2 emissions and fuel consumption related properties shall be selected from the air drag type or air drag family representing the highest production numbers in the corresponding year. Any additional vehicles shall be selected from all air drag families and shall be agreed between the manufacturer and the approval authority based on the air drag families and vehicle groups already tested. If only one test per year or less has to be executed, the vehicle shall always be selected from all air drag families and shall be agreed between the manufacturer and the approval authority.

▼B

5. After a vehicle was selected for conformity of the certified CO_2 emissions and fuel consumption related properties the manufacturer has to verify the conformity of the certified CO_2 emissions and fuel consumption related properties within a time period of 12 month. The manufacturer may request the approval authority for an extension of that period for up to 6 months if he can prove that the verification was not possible within the required period due to weather conditions.

▼**M3**

Appendix 7

Standard values

This Appendix describes standard values for the declared air drag value $C_d \cdot A_{declared}$. Where standard values are applied, no input data on air drag shall be provided to the simulation tool. In this case, the standard values are allocated automatically by the simulation tool.

1. Standard values for heavy lorries are defined in accordance with Table 18.

Table 18

Standard values for $C_d \cdot A_{declared}$ for heavy lorries

Vehicle group	Standard value $C_d \cdot A_{declared}$ [m^2]
1, 1s	7,1
2	7,2
3	7,4
4	8,4
5	8,7
9	8,5
10	8,8
11	8,5
12	8,8
16	9,0

2. —

3. —

4. Standard values for heavy buses are defined in accordance with Table 21. For vehicle groups for which no measurement of aerodynamic drag is allowed (in accordance with point 7.3. in Appendix 5 of this Annex), standard values are not relevant.

Table 21

Standard values for $C_d \cdot A_{declared}$ for heavy buses

Vehicle parameter sub-group	Standard value $C_d \cdot A_{declared}$ [m^2]
31a	not relevant
31b1	not relevant
31b2	4,9
31c	not relevant
31d	not relevant
31e	not relevant
32a	4,6
32b	4,6

▼**M3**

Vehicle parameter sub-group	Standard value $C_d{\cdot}A_{declared}$ [m²]
32c	4,6
32d	4,6
32e	5,2
32f	5,2
33a	not relevant
33b1	not relevant
33b2	5,0
33c	not relevant
33d	not relevant
33e	not relevant
34a	4,7
34b	4,7
34c	4,7
34d	4,7
34e	5,3
34f	5,3
35a	not relevant
35b1	not relevant
35b2	5,1
35c	not relevant
36a	4,8
36b	4,8
36c	4,8
36d	4,8
36e	5,4
36f	5,4
37a	not relevant
37b1	not relevant
37b2	5,1
37c	not relevant
37d	not relevant

▼**M3**

Vehicle parameter sub-group	Standard value $C_d \cdot A_{declared}$ [m²]
37e	not relevant
38a	4,8
38b	4,8
38c	4,8
38d	4,8
38e	5,4
38f	5,4
39a	not relevant
39b1	not relevant
39b2	5,2
39c	not relevant
40a	4,9
40b	4,9
40c	4,9
40d	4,9
40e	5,5
40f	5,5

5. Standard values for medium lorries are defined in accordance with Table 22.

Table 22

Standard values for $C_d \cdot A_{declared}$ for medium lorries

Vehicle group	Standard value $C_d \cdot A_{declared}$ [m²]
53	5,8
54	2,5

▼B

Appendix 8

▼M3

Markings

In the case of a vehicle being certified in accordance with this Annex, the cabin or the bodywork shall bear:

▼M1

1.1. The manufacturer's name or trade mark

▼B

1.2 The make and identifying type indication as recorded in the information referred to in paragraph 0.2 and 0.3 of Appendix 2 to this Annex

1.3 The certification mark as a rectangle surrounding the lower-case letter 'e' followed by the distinguishing number of the Member State which has granted the certificate:

1 for Germany;

2 for France;

3 for Italy;

4 for the Netherlands;

5 for Sweden;

6 for Belgium;

7 for Hungary;

8 for the Czech Republic;

9 for Spain;

11 for the United Kingdom;

12 for Austria;

13 for Luxembourg;

17 for Finland;

18 for Denmark;

19 for Romania;

20 for Poland;

21 for Portugal;

23 for Greece;

24 for Ireland;

25 for Croatia;

26 for Slovenia;

27 for Slovakia;

29 for Estonia;

32 for Latvia;

34 for Bulgaria;

36 for Lithuania;

49 for Cyprus;

50 for Malta

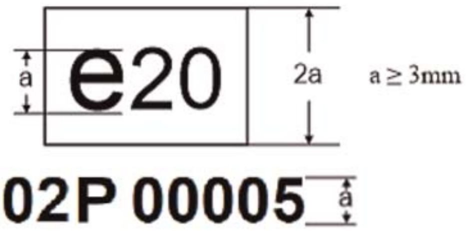
▼B

1.4 ►M3 The certification mark shall also include in the vicinity of the rectangle the 'base certification number' as specified for Section 4 of the type-approval number set out in Annex I to Regulation (EU) 2020/683 preceded by the two figures indicating the sequence number assigned to the latest technical amendment to this Regulation and by a character 'P' indicating that the approval has been granted for airdrag.

For this Regulation the sequence number shall be 02. ◄

▼M3

1.4.1 Example and dimensions of the certification mark



The above certification mark affixed to a cabin shows that the type concerned has been certified in Poland (e20), pursuant to this Regulation. The first two digits (02) are indicating the sequence number assigned to the latest technical amendment to this Regulation. The following letter indicates that the certificate was granted for air drag (P). The last five digits (00005) are those allocated by the approval authority for the air drag as the base certification number.

▼B

1.5 The certification mark shall be affixed to the cabin in such a way as to be indelible and clearly legible. It shall be visible when the cabin is installed on the vehicle and shall be affixed to a part necessary for normal cabin operation and not normally requiring replacement during cabin life. ►M1 The markings, labels, plates or stickers must be durable for the useful life of the cabin and must be clearly legible and indelible. ◄ The manufacturer shall ensure that the markings, labels, plates or sticker cannot be removed without destroying or defacing them.

2 Numbering

▼M3

2.1. Certification number for air drag shall comprise the following:

eX*YYYY/YYYY*ZZZZ/ZZZZ*P*00000*00

section 1	section 2	section 3	Additional letter to section 3	section 4	section 5
Indication of country issuing the certificate	HDV CO_2 determination Regulation '2017/2400'	Latest amending Regulation (ZZZZ/ZZZZ)	P = Air drag	Base certification number 00000	Extension 00

▼M1

Appendix 9

Input parameters for the simulation tool

Introduction

This Appendix describes the list of parameters to be provided by the vehicle manufacturer as input to the simulation tool. The applicable XML schema as well as example data are available at the dedicated electronic distribution platform.

The XML is automatically generated by the air drag pre-processing tool.

Definitions

(1) 'Parameter ID': Unique identifier as used in the simulation tool for a specific input parameter or set of input data

(2) 'Type': Data type of the parameter

string .... sequence of characters in ISO8859-1 encoding

token .... sequence of characters in ISO8859-1 encoding, no leading/trailing whitespace

date .... date and time in UTC time in the format: YYYY-MM-DD***T***HH:MM:SS***Z*** with italic letters denoting fixed characters e.g. '2002-05-30T09:30:10Z'

integer .... value with an integral data type, no leading zeros, e.g. '1800'

double, X .... fractional number with exactly X digits after the decimal sign ('.') and no leading zeros e.g. for 'double, 2': '2345.67'; for 'double, 4': '45.6780'

(3) 'Unit' … physical unit of the parameter

Set of input parameters

Table 1

Input parameters 'AirDrag'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P240	token		
Model	P241	token		
Certification-Number	P242	token		Identifier of the component as used in the certification process
Date	P243	date		Date and time when the component hash is created
AppVersion	P244	token		Number identifying the version of the air drag pre-processing tool
CdxA_0	P245	double, 2	[m^2]	Final result of the air drag pre-processing tool.

▼M1

Parameter name	Parameter ID	Type	Unit	Description/Reference
▼M3				
TransferredCdxA	P246	double, 2	[m^2]	CdxA_0 transferred to related families in other vehicle groups in accordance with Table 16 of Appendix 5 for heavy lorries, Table 16a of Appendix 5 for medium lorries and Table 16b of Appendix 5 for heavy buses. Where no transfer rule was applied, CdxA_0 shall be provided.
▼M1				
DeclaredCdxA	P146	double, 2	[m^2]	Declared value for air drag family

In case standard values in accordance with Appendix 7 shall be used in the simulation tool, no input data for air drag component shall be provided. The standard values are allocated automatically in accordance with the vehicle group scheme.

▼M3

ANNEX IX

VERIFYING LORRY AND BUS AUXILIARY DATA

1. Introduction

This Annex describes the provisions regarding declaration of technologies and other relevant input information on auxiliary systems for heavy duty vehicles for the purpose of the determination of vehicle specific CO_2 emissions.

The power consumption of the following auxiliary types shall be considered within the simulation tool by using technology specific average generic models for power consumption:

(a) Engine cooling fan

(b) Steering system

(c) Electric system

(d) Pneumatic system

(e) Heating, ventilation and air conditioning (HVAC) system

(f) Transmission Power Take Off (PTO)

The generic values are integrated in the simulation tool and automatically used based on the relevant input information in accordance with the provisions in this Annex. The related input data formats for the simulation tool are described in Annex III. For a clear reference, the three-digit parameter IDs used in Annex III are also listed in this Annex.';

2. Definitions

For the purposes of this Annex the following definitions shall apply. The related auxiliary type is stated in brackets.

(1) 'crankshaft mounted' fan means a fan installation where the fan is driven in the prolongation of the crankshaft, often by a flange (engine cooling fan);

(2) 'belt or transmission driven' fan means a fan that is installed in a position where additional belt, tension system or transmission is needed (engine cooling fan);

(3) 'hydraulic driven' fan means a fan propelled by hydraulic oil, often installed away from the engine. A hydraulic system with oil system, pump and valves are influencing losses and efficiencies in the system (engine cooling fan);

(4) 'electrically driven' fan means a fan propelled by an electric motor. The efficiency for complete energy conversion, included in/out from battery, is considered (engine cooling fan);

(5) 'electronically controlled visco clutch' means a clutch in which a number of sensor inputs together with SW logic are used to electronically actuate the fluid flow in the visco clutch (engine cooling fan);

▼**M3**

(6) ‘bimetallic controlled visco clutch’ means a clutch in which a bimetallic connection is used to convert a temperature change into mechanical displacement. The mechanical displacement is then working as an actuator for the visco clutch (engine cooling fan);

(7) ‘discrete step clutch’ means a mechanical device where the grade of actuation can be made in distinct steps only (not continuous variable) (engine cooling fan);

(8) ‘on/off clutch’ means a mechanical clutch which is either fully engaged or fully disengaged (engine cooling fan);

(9) ‘variable displacement pump’ means a device that converts mechanical energy to hydraulic fluid energy. The amount of fluid pumped per revolution of the pump can be varied while the pump is running (engine cooling fan);

(10) ‘constant displacement pump’ means a device that converts mechanical energy to hydraulic fluid energy. The amount of fluid pumped per revolution of the pump cannot be varied while the pump is running (engine cooling fan);

(11) ‘electric motor control’ means the use of an electric motor to propel the fan. The electrical machine converts electrical energy into mechanical energy. Power and speed are controlled by conventional technology for electric motors (engine cooling fan);

(12) ‘fixed displacement pump (default technology)’ means a pump having an internal limitation of the flow rate (steering system);

(13) ‘fixed displacement pump with electronic control’ means a pump using an electronic control of the flow rate (steering system);

(14) ‘dual displacement pump’ means a pump with two chambers (with the same or different displacement) mechanical internal limitation of flow rate (steering system);

(14a) ‘dual displacement pump with electronic control’ means a pump with two chambers (with the same or different displacement) which can be combined or where under specific conditions only one of these is used. The flow rate is electronically controlled by a valve (steering system);

(15) ‘variable displacement pump mech. controlled’ means a pump where the displacement is mechanically controlled internally (internal pressure scales) (steering system);

(16) ‘variable displacement pump elec. controlled’ means a pump where the displacement is electronically controlled (steering system);

(17) ‘electric driven pump’ means a steering system driven by an electric motor with continuously recirculating hydraulic fluid (steering system);

(17a) ‘full electric steering gear’ means a steering system driven by an electric motor without continuously recirculating hydraulic fluid (steering system);

(18) -

(19) ‘air compressor with energy saving system’ or ‘ESS’ means a compressor reducing the power consumption during blow off, e.g. by closing intake side, ESS is controlled by system air pressure (pneumatic system);

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(20) 'compressor clutch (visco)' means a disengageable compressor where the clutch is controlled by the system air pressure (no smart strategy), minor losses during disengaged state caused by visco clutch (pneumatic system);

(21) 'compressor clutch (mechanically)' means a disengageable compressor where the clutch is controlled by the system air pressure (no smart strategy) (pneumatic system);

(22) 'air management system with optimal regeneration' or 'AMS' means an electronic air processing unit that combines an electronically controlled air dryer for optimised air regeneration and an air delivery preferred during overrun conditions (requires a clutch or ESS) (pneumatic system).

(23) 'light emitting diode' or 'LED' means semiconductor devices that emit visible light when an electrical current passes through them (electric system);

(24) -

(25) 'power take-off' or 'PTO' means a device on a transmission or an engine to which an optional power consuming device ('consumer'), e.g., a hydraulic pump, can be connected; a power take-off is usually optional (PTO);

(26) 'power take-off drive mechanism' means a device in a transmission that allows the installation of a power take-off (PTO);

(26a) 'engaged gearwheel' means a gearwheel which is engaged with running shafts of either the engine or transmission while the PTO clutch (if applicable) is open (PTO);

(27) 'tooth clutch' means a (manoeuvrable) clutch where torque is transferred mainly by normal forces between mating teeth. A tooth clutch can either be engaged or disengaged. It is operated in load-free conditions only (e.g. at gear shifts in a manual transmission) (PTO);

(28) 'synchroniser' means a type of tooth clutch where a friction device is used to equalise the speeds of the rotating parts to be engaged (PTO);

(29) 'multi-disc clutch' means a clutch where several friction linings are arranged in parallel whereby all friction pairs get the same pressing force. Multi-disc clutches are compact and can be engaged and disengaged under load. They may be designed as dry or wet clutches (PTO);

(30) 'sliding wheel' means a gearwheel used as shift element where the shifting is realised by moving the gearwheel on its shaft into or out of the gear mesh of the mating gear (PTO);

(31) 'discrete step clutch (off + 2 stages)' means a mechanical device where the grade of actuation can be made in two distinct steps plus off only (not continuous variable) (engine cooling fan);

(32) 'discrete step clutch (off + 3 stages)' means a mechanical device where the grade of actuation can be made in three distinct steps plus off only (not continuous variable) (engine cooling fan);

▼**M3**

(33) ‘ratio compressor to engine’ means the forward gear ratio of the speed of the engine to the speed of the air compressor without slip ($i = n_{in}/n_{out}$) (pneumatic system);

(34) ‘air suspension control mechanically’ means an air supension system in which the air suspension control valves are operated mechanically without electronics and software (pneumatic system);

(35) ‘air suspension control electronically’ means an air supension system in which a number of sensor inputs together with software logic are used to electronically actuate the air suspension control valves (pneumatic system);

(36) ‘pneumatic SCR reagent dosing’ means that compressed air is used for dosing reagent into the exhaust system (pneumatic system);

(37) ‘door drive technology pneumatic’ means that the passenger doors of the vehicle are operated with compressed air (pneumatic system);

(38) ‘door drive technology electric’ means that the passenger doors of the vehicle are operated with an electric motor or with an electrohydraulic system (pneumatic system);

(39) ‘door drive technology mixed’ means that both ‘door drive technology pneumatic’ and ‘door drive technology electric’ are installed in the vehicle (pneumatic system);

(40) ‘smart regeneration system’ means a pneumatic system in which the regeneration air demand is optimised with respect to the quantity of dried air that is produced (pneumatic system);

(41) ‘smart compression system’ means a pneumatic system in which the air delivery is electronically controlled with preferred air delivery during overrun conditions (pneumatic system);

(42) ‘interior lights’ means the lights within the passenger compartment that are installed to fulfil the requirements of paragraph 7.8. (artificial interior lighting) in Annex 3 to UN Regulation No. 107 ([1]) (electric system);

(43) ‘day running lights’ means the ‘daytime running lamp’ in accordance with paragraph 2.7.25 of UN Regulation No. 48 ([2]) (electric system);

(44) ‘position lights’ means the ‘side marker lamp’ in accordance with paragraph 2.7.24 of UN Regulation No. 48 (electric system);

(45) ‘brake lights’ means the ‘stop lamp’ in accordance with paragraph 2.7.12 of UN Regulation No. 48 (electric system);

(46) ‘headlights’ means the ‘passing-beam (dipped-beam) headlamp’ in accordance with paragraph 2.7.10 of UN Regulation No. 48, and the ‘driving-beam (main-beam) headlamp’ in accordance with paragraph 2.7.9 of UN Regulation No. 48 (electric system);

([1]) Regulation No 107 of the Economic Commission for Europe of the United Nations (UNECE) – Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction (OJ L 52, 23.2.2018, p. 1).

([2]) Regulation No 48 of the Economic Commission for Europe of the United Nations (UNECE) – Uniform provisions concerning the approval of vehicles with regard to the installation of lighting and light-signalling devices (OJ L 14, 16.1.2019, p. 42).

▼M3

(47) ‘alternator’ means an electric machine to charge the battery and to supply electric power to the electrical auxiliary system when the vehicle’s internal combustion engine is running. An alternator can not contribute to propulsion of the vehicle (electric system);

(48) ‘smart alternator system’ means a system of one ore more alternators in combination with one or more dedicated REESS which is electronically controlled with preferred generation of electic energy during overrun conditions (electric system);

(49) ‘heating, ventilation and air conditioning system’ or HVAC system means a system that can actively heat and/or actively cool down and exchange or replace air to provide improved air qualityfor the passenger and/or the driver compartment (HVAC system);

(50) ‘HVAC system configuration’ means a combination of HVAC system components in accordance with Table 13 of this Annex (HVAC system);

(51) ‘thermal comfort system for passenger compartment’ means a system that uses fans to circulate air within the vehicle or blows fresh air into the vehicle and the air volume flow can at least be actively cooled or heated. The air is distributed from the roof of the vehicle and in the case of double deckers, in both floors. In the case of open top double deckers, in the lower deck (HVAC system);

(52) ‘number of heat pumps for passenger compartment’ means the number of heat pumps that are installed in the vehicle to heat up and/or cool down cabin air or fresh air supplied to the passenger compartment. If a heat pump is used for the passenger and for the driver compartment it is counted for the passenger compartment only (HVAC system). If different heat pumps for heating and cooling are installed, the number of heat pumps shall be defined by the lower number of both separate cases – i.e. the number of heat pumps for cooling and the number of heat pumps for heating shall be considered separately (e.g. in the case of 2 heat pumps for cooling and 1 heat pump for heating: only 1 heat pump shall be considered);

(53) ‘air conditioning system for driver compartment’ means that a system is installed in the vehicle that can cool down the cabin air or fresh air supplied to the driver or driver compartment (HVAC system);

(54) ‘air conditioning system for passenger compartment’ means that a system is installed in the vehicle that can cool down the cabin air or fresh air supplied to the passenger compartment (HVAC system);

(55) ‘independent heat pump for driver compartment’ means that a heat pump is installed in the vehicle that is only used for the driver compartment (HVAC system);

(56) ‘heat pump 2-stage’ means a heat pump where the grade of actuation can be made in two steps only but not continuous variable (HVAC system);

(57) ‘heat pump 3-stage’ means a heat pump where the grade of actuation can be made in three steps only but not continuous variable (HVAC system);

(58) ‘heat pump 4-stage’ means a heat pump where the grade of actuation can be made in four steps only but not continuous variable (HVAC system);

▼M3

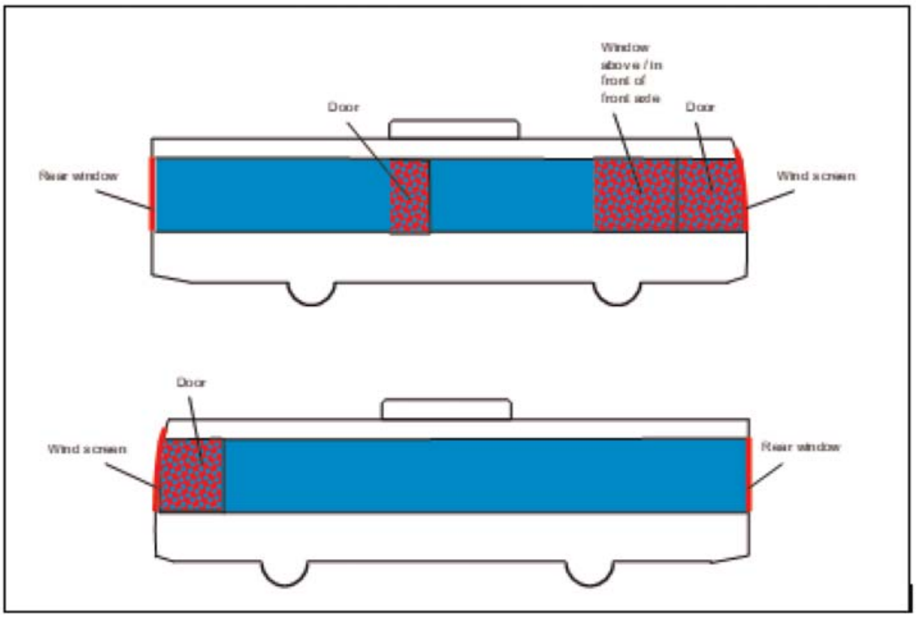
(59) ‘heat pump continuous’ means a heat pump where the grade of actuation is continuously variable or where the air conditioning compressor is driven by an electric motor with continuously variable speed (HVAC system);

(60) ‘auxiliary heater power’ as stated on the label defined in paragraph 4 of Annex 7 to UN Regulation No. 122 ([1]) (HVAC system);

(61) ‘double glazing’ means windows of the passenger compartment that consist of two glass window panes that are separated by gas filled space or by vacuum. In the case of several types of windows within the passenger compartment, the predominant window type with regards to surface area has to be selected. For the assessment of the predominant window type the windscreen, the rear window, the driver side-window(s), windows within doors, windows above and in front of the front axle (see Figure 1 for examples) as well as tiltable windows, shall not be considered (HVAC system);

Figure 1

Windows not to be considered for predominant window type



(62) ‘heat pump’ means a system that uses a refrigerant in a circular process to transfer thermal energy from the environment to the passenger compartment and/or the driver compartment and/or transfers thermal energy in the opposite direction (cooling and/or heating functionality) with a coefficient of performance larger than 1 (HVAC system);

(63) ‘R-744 heat pump’ means a heat pump which uses R-744 refrigerant as working medium (HVAC system);

(64) ‘non R-744 heat pump’ means a heat pump which uses another working medium than R-744 refrigerant. For the possible grade of actuation (2-stage, 3-stage, 4-stage, continuous), the definitions (56) to (59) shall apply (HVAC system);

([1]) Regulation No 122 of the Economic Commission for Europe of the United Nations (UN/ECE) – Uniform technical prescriptions concerning the approval of vehicles of categories M, N and O with regard to their heating systems (OJ L 19, 24.1.2020, p. 42).

▼M3

(65) ‘adjustable coolant thermostat’ means a coolant thermostat which characteristics are influenced by at least one additional input besides the coolant temperature, e.g. active electric heating of the thermostat (HVAC system);

(66) ‘adjustable auxiliary heater’ means a fuel-operated heater with at least 2 levels of heating capacity besides ‘off’ that can be controlled depending on the required heating system capacity in the bus (HVAC system);

(67) ‘engine waste gas heat exchanger’ means a heat exchanger that uses the thermal energy of engine waste gas to heat the cooling circuit (HVAC system);

(68) ‘separate air distribution ducts’ means one or multiple air channels connected to a thermal comfort system to distribute conditioned air evenly to the passenger compartment. Air channels may include loud speakers or HVAC water supply and electric harness. Reservoirs for compressed airs shall not be installed within this/these channel/s. By this model parameter the simulation tool considers reduced heat transfer losses to the ambient or components within the channel. For HVAC configurations 8, 9 and 10 in vehicle groups 31, 33, 35, 37 and 39, this input shall be set to ‘true’ as those configurations benefit from reduced losses as cooled air is directly blown into vehicle interior even without any air channel. For all HVAC configurations in vehicle groups 32, 34, 36, 38 and 40 this parameter shall be set to ‘true’ as this is state-of-the-art (HVAC system);

(69) ‘electrically driven compressor’ means a compressor driven by an electric motor (pneumatic system);

(70) ‘water electric heater’ means a device using electric energy to heat up the coolant of the vehicle with a coefficient of performance lower than 1 and that is actively used for the heating functionality during vehicle operation on road (HVAC system);

(71) ‘air electric heater’ means a device using electric energy to heat up the air of the passenger and/or driver compartment with a coefficient of performance lower than 1 (HVAC system);

(72) ‘other heating technology’ means any fully electric technology used for heating up the passenger and/or driver compartment not covered by the technologies in definitons (62), (70) or (71) (HVAC system);

(73) ‘lead-acid battery – conventional’ means a lead-acid battery where none of the definitions (74) or (75) applies (electric system);

(74) ‘lead-acid battery –AGM’ (Absorbed Glass Mat) means lead-acid batteries where glass fibre mats soaked in electrolyte are used as separators between the negative and positive plates (electric system);

(75) ‘lead-acid battery – gel’ means lead-acid batteries where a silica gelling agent is mixed into the electrolyte (electric system);

(76) ‘Li-ion battery - high power’ means a Li-ion battery where the numerical ratio between rated maximum current in [A] and the rated capacity in [Ah] is equal to or larger than 10 (electric system);

▼M3

(77) ‘Li-ion battery - high energy’ means a Li-ion battery where the numerical ratio between rated maximum current in [A] and the rated capacity in [Ah] is less than 10 (electric system);

(78) ‘capacitor with DC/DC converter’ means an (ultra) capacitor electrical energy storage unit combined with a DC/DC unit that adapts the voltage level and controls the current to and from the electric consumer board net (electric system);

(79) ‘articulated bus’ means a heavy bus that is an incomplete vehicle, complete vehicle or completed vehicle consisting of at least two rigid sections connected to each other by an articulated section. Connection and disconnection of the sections are to be possible only in a workshop. For the complete or completed heavy buses of this type of vehicle, the articulated section shall permit the free movement of travellers between the rigid sections.

3. Description of auxiliary relevant input information into the simulation tool

3.1. Engine cooling fan

The information on engine cooling fan technology shall be provided based on the applicable combinations of fan drive and fan control technology as described in Table 4 below.

If a new technology within a fan drive cluster (e.g. crankshaft mounted) cannot be found in the list, the technology allocated to ‘default for fan drive cluster’ shall be provided.

If a new technology cannot be found in any fan drive cluster the technology allocated to ‘default overall’ shall be provided.

Table 4

Engine cooling fan technologies (P181)

Fan drive cluster	Fan control	Medium and heavy lorries	Heavy buses
Crankshaft mounted	Electronically controlled visco clutch	X	X
	Bimetallic controlled visco clutch	X (DC)	X
	Discrete step clutch	X	
	Discrete step clutch (off + 2 stages)		X
	Discrete step clutch (off + 3 stages)		X
	On/off cluch	X	X (DC, DO)

▼M3

Fan drive cluster	Fan control	Medium and heavy lorries	Heavy buses
Belt driven or driven via transmission	Electronic controlled visco clutch	X	X
	Bimetallic controlled visco clutch	X (DC)	X
	Discrete step clutch	X	
	Discrete step clutch (off + 2 stages)		X
	Discrete step clutch (off + 3 stages)		X
	On/off cluch	X	X (DC)
Hydraulically driven	Variable displacement pump	X	X
	Constant displacement pump	X (DC, DO)	X (DC)
Electrically driven	Electric motor control	X (DC)	X (DC)

X: applicable, DC: default for fan drive cluster, DO: default overall

3.2. Steering system

The technology of the steering system shall be provided in accordance with Table 5 per each active steered axle on the vehicle.

If a new technology within a steering technology cluster (e.g. mechanically driven) cannot be found in the list, the technology allocated to ‘default for steering technology cluster’ shall be provided. If a new technology cannot be found in any steering technology cluster the technology allocated to ‘default overall’ shall be provided.

Table 5

Steering system technologies (P182)

Steering technology cluster	Technology	Medium and heavy lorries	Heavy buses
Mechanically driven	Fixed displacement	X (DC, DO)	X (DC, DO)
	Fixed displacement, electronical control	X	X
	Dual displacement pump	X	X
	Dual displacement pump with electronic control	X	X
	Variable displacement, mechanical control	X	X
	Variable displacement, electronical control	X	X
Electric	Electric driven pump	X (DC)	X (DC)
	Full electric steering gear	X	X

X: applicable, DC: default for steering technology cluster, DO: default overall

▼**M3**

3.3. Electric System

3.3.1. Medium lorries and heavy lorries

The technology of the electric system shall be provided in accordance with

Table *6*.

If the technology used in the vehicle is not listed, 'standard technology' shall be provided to the simulation tool.

Table 6

Electric system technologies for medium lorries and heavy lorries (P183)

Technology
Standard technology
Standard technology - LED headlights

3.3.2. Heavy buses

The technology of the electric system shall be provided in accordance with Table 7.

Table 7

Electric system technologies for heavy buses

Electric system cluster	Parameter	Parameter (ID)	Input to the simulation tool	Explanations
Alternator	Alternator technology	P294	conventional / smart / no alternator	'smart' shall be declared for systems fulfilling the definitions as given in point 2(48); 'no alternator' is applicable for HEVs which do not have an alternator in the electric auxiliary system. For PEVs no input is required.
	Smart alternator – maximum rated current	P295	value in [A]	Maximum rated current at nominal speed in accordance with manufacturer's labelling or data sheet, or measured in accordance with standard ISO 8854:2012 Input per smart alternator
	Smart alternator – rated voltage	P296	value in [V]	Allowed values: '12', '24', '48' Input per smart alternator

▼M3

Electric system cluster	Parameter	Parameter (ID)	Input to the simulation tool	Explanations
Batteries for smart alternator systems	Technology	P297	lead-acid battery – conventional / lead-acid battery – AGM / lead-acid battery – gel / li-ion battery - high power / li-ion battery - high energy	Input per battery charged by smart alternator system If a battery technology cannot be found in the list, the technology 'Lead-acid battery – Conventional' shall be provided as input.
	Nominal voltage	P298	value in [V]	Allowed values: '12', '24', '48' Input per battery charged by smart alternator system Where batteries are configured in series (e.g. two 12V units for a 24V system), the actual nominal voltage of the single battery units (12V in this example) shall be provided.
	Rated capacity	P299	value in [Ah]	Capacity in Ah in accordance with manufacturer's labelling or data sheet Input per battery charged by smart alternator system
Capacitors for smart alternator systems	Technology	P300	with DC/DC converter	Input per battery charged by smart alternator system
	Rated capacitance	P301	value in [F]	Capacitance in Farad (F) in accordance with manufacturer's labelling or data sheet Input per capacitor charged by smart alternator system
	Rated voltage	P302	value in [V]	Rated operating voltage in accordance with manufacturer's labelling or data sheet Input per capacitor charged by smart alternator system
Auxiliary electric energy supply	Supply of electric auxiliaries from HEV REESS possible	P303	true / false	To be set to 'true' if the vehicle is equipped with a controlled power link that enables transfer of electric energy from a HEV propulsion energy storage system to the electric consumer board net. Input only required for HEV.

▼**M3**

Electric system cluster	Parameter	Parameter (ID)	Input to the simulation tool	Explanations
Interior lights	Interior lights LED	P304	true / false	Parameters shall only be set to true if all lights of the category are in line with the definitions set out in points 2(42) to 2(46).
Exterior lights	Day running lights LED	P305	true / false	
	Position lights LED	P306	true / false	
	Brake lights LED	P307	true / false	
	Headlights LED	P308	true / false	

3.4. Pneumatic system

3.4.1. Pneumatic systems working with over pressure

3.4.1.1. Size of air supply

For pneumatic systems working with over pressure the size of air supply shall be provided in accordance with Table 8.

Table 8

Pneumatic systems with over pressure – size of air supply

Size of air supply	Medium and heavy lorries (part of P184)	Heavy buses (P309)
Small displacement ≤ 250 cm^3; 1 cylinder / 2 cylinder	X	X
Medium 250 cm^3 < displacement ≤ 500 cm^3; 1 cylinder / 2 cylinder 1-stage	X	X
Medium 250cm^3 < displacement ≤ 500 cm^3; 1 cylinder / 2 cylinder 2-stage	X	X
Large displacement > 500 cm^3; 1 cylinder / 2 cylinder 1-stage / 2-stage	X, DO	
Large displacement > 500 cm^3; 1-stage		X, DO
Large displacement > 500 cm^3; 2-stage		X

In the case of a two-stage compressor, the displacement of the first stage shall be used to describe the size of the air compressor system. In the case of non-piston compressors, the ‘default overall’ (DO) technology shall be declared.

In the case of heavy buses with electrically driven compressors, ‘not applicable’ shall be provided as input for size of air supply as this parameter is not considered by the simulation tool.

▼M3

3.4.1.2. Fuel saving technologies

Fuel saving technologies shall be provided in accordance with the combinations as listed in Table 9 for medium and heavy lorries in Table 10 for heavy buses.

Table 9

Pneumatic systems with over pressure – fuel saving technologies for heavy lorries, medium lorries (part of P184)

Combination No	Compressor drive	Compressor clutch	Air compressor with Energy Saving System (ESS)	Air Management System with optimal regeneration (AMS)
1	mechanically	no	no	no
2	mechanically	no	yes	no
3	mechanically	visco	no	no
4	mechanically	mechanically	no	no
5	mechanically	no	yes	yes
6	mechanically	visco	no	yes
7	mechanically	mechanically	no	yes
8	electrically	no	no	no
9	electrically	no	no	yes

Table 10

Pneumatic systems with over pressure – fuel saving technologies for heavy buses

Combination No	Compressor drive (P310)	Compressor clutch (P311)	Smart regeneration system (P312)	Smart compression system (P313)
1	mechanically	no	no	no
2	mechanically	no	yes	no
3	mechanically	no	no	yes
4	mechanically	no	yes	yes
5	mechanically	visco	no	no
6	mechanically	visco	yes	no
7	mechanically	visco	no	yes
8	mechanically	visco	yes	yes
9	mechanically	mechanical	no	no
10	mechanically	mechanical	yes	no
11	mechanically	mechanical	no	yes
12	mechanically	mechanical	yes	yes
13	electrically	no	no	no
14	electrically	no	yes	no

▼**M3**

3.4.1.3. Further characteristics of the pneumatic system for heavy buses

For heavy buses the information on further characteristics of the pneumatic system shall be provided in accordance with Table 11.

Table 11

Further characteristics of the pneumatic system for heavy buses

Parameter	Parameter ID	Input to the simulation tool	Explanations
Ratio compressor to engine	P314	value in [-]	Ratio = compressor speed / engine speed. Only applicable in the case of mechanically driven compressor
Entrance height in non-kneeled position	P290	value in [mm]	In accordance with the definitions as set out in point 2(10) of Annex III. Documentation of this value shall be given by vehicle setup drawings used during parametrisation of the air suspension control of the vehicle. Value shall represent the state as delivered to the customer as normal ride height. This parameter is only relevant for heavy buses.
Air suspension control	P315	mechanically / electronically	
Pneumatic SCR reagent dosing	P316	true / false	See point 2(36)
Door drive technology	P291	pneumatic / mixed / electric	

3.4.2. Pneumatic systems working with vacuum

For vehicles with pneumatic systems working with vacuum (relative negative pressure) either ‘Vacuum pump’ or ‘Vacuum pump + elec. driven’ shall be provided as input to the simulation tool (P184). This technology is not applicable for heavy buses.

3.5. HVAC system

3.5.1. HVAC system for medium lorries and heavy lorries

The technology of the HVAC system shall be provided in accordance with Table 12.

▼**M3**

Table 12

HVAC system technologies for medium lorries and heavy lorries (P185)

Technology
None (no air conditioning system for driver compartment)
Default

3.5.2. HVAC system for heavy buses

The HVAC system configuration shall be provided in accordance with the definitions set out in Table 13. A graphical representation of the different configurations is given in Figure 2.

Table 13

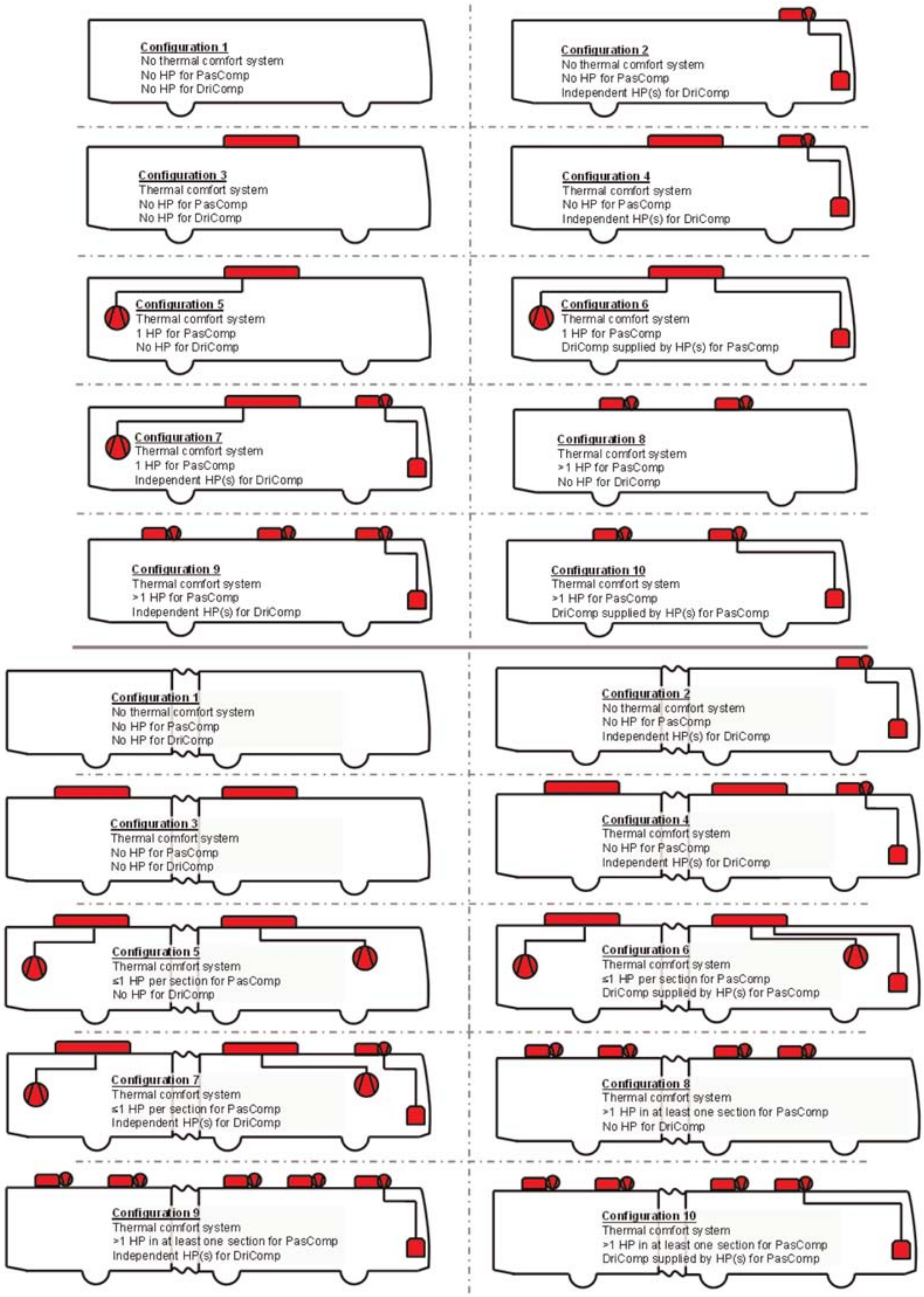
HVAC system configuration for heavy buses (P317)

HVAC system configuration	Thermal comfort system for passenger compartment	Number of heat pumps for passenger compartment in accordance with (52) of point 2		Driver compartment supplied by heat pump(s) for passenger compartment	Independent heat pump(s) for driver compartment
		Rigid	Articu-lated		
1	No	0	0	No	No
2	No	0	0	No	Yes
3	Yes	0	0	No	No
4	Yes	0	0	No	Yes
5	Yes	1	1 or 2	No	No
6	Yes	1	1 or 2	Yes	No
7	Yes	1	1 or 2	No	Yes
8	Yes	> 1	> 2	No	No
9	Yes	> 1	> 2	No	Yes
10	Yes	> 1	> 2	Yes	No

▼M3

Figure 2

HVAC system configuration for heavy buses (Rigid and Articulated)



Abbreviations used in figure:

HP ... heat pump PasComp ... passenger compartment DriComp ... driver compartment

▼M3

The HVAC system parameters shall be declared in accordance with Table 14.

Table 14

HVAC system parameters (heavy buses)

Parameter	Parameter ID	Input to the simulation tool	Explanations
Heat pump type for cooling driver compartment	P318	none / not applicable / R-744 / non R-744 2-stage / non R-744 3-stage / non R-744 4-stage / non R-744 continuous	'not applicable' shall be declared for HVAC system configurations 6 and 10 due to supply from passenger heat pump
Heat pump type for heating driver compartment	P319	none / not applicable / R-744 / non R-744 2-stage / non R-744 3-stage / non R-744 4-stage / non R-744 continuous	'not applicable' shall be declared for HVAC system configurations 6 and 10 due to supply from passenger heat pump
Heat pump type for cooling passenger compartment	P320	none / R-744 / non R-744 2-stage / non R-744 3-stage / non R-744 4-stage / non R-744 continuous	In the case of multiple heat pumps with different technologies for cooling the passenger compartment, the dominant technology shall be declared (e.g. in accordance with available power or preferred usage in operation).
Heat pump type for heating passenger compartment	P321	none / R-744 / non R-744 2-stage / non R-744 3-stage / non R-744 4-stage / non R-744 continuous	In the case of multiple heat pumps with different technologies for heating the passenger compartment, the dominant technology shall be declared (e.g. in accordance with available power or preferred usage in operation).
Auxiliary heater power	P322	value in [W]	Rated output as specified for the device; Enter '0' if no auxiliary heater is installed.
Double glazing	P323	true / false	
Adjustable coolant thermostat	P324	true / false	
Adjustable auxiliary heater	P325	true / false	
Engine waste gas heat exchanger	P326	true / false	
Separate air distribution ducts	P327	true / false	
Water electric heater	P328	true / false	Input to be provided only for HEV and PEV
Air electric heater	P329	true / false	Input to be provided only for HEV and PEV
Other heating technology	P330	true / false	Input to be provided only for HEV and PEV

▼M3

3.6 Transmission Power Take-Off (PTO)

For heavy lorries with PTO and/or PTO drive mechanism installed on the transmission, the power consumption shall be considered by determined generic values. Those represent these power losses in usual drive mode when the consumer connected to a PTO, e.g. a hydraulic pump, is switched off/disengaged. Application related power consumptions at engaged consumer are added by the simulation tool and are not described in the following.

Table 12

Mechanical power demand of PTOs with switched off consumers for heavy lorries

Design variants regarding power losses (in comparison to a transmission without PTO and / or PTO drive mechanism)		Power loss
Additional drag loss relevant parts		
Shafts / gear wheels (P247)	Other elements (P248)	[W]
only one engaged gearwheel positioned above the specified oil level (no additional gearmesh)	—	0
only the drive shaft of the PTO	tooth clutch (incl. synchroniser) or sliding gearwheel	50
only the drive shaft of the PTO	multi-disc clutch	350
only the drive shaft of the PTO	multi-disc clutch with dedicated pump for PTO clutch	3 000
drive shaft and/or up to 2 engaged gearwheels	tooth clutch (incl. synchroniser) or sliding gearwheel	150
drive shaft and/or up to 2 engaged gearwheels	multi-disc clutch	400
drive shaft and/or up to 2 engaged gearwheels	multi-disc clutch with dedicated pump for PTO clutch	3 050
drive shaft and/or more than 2 engaged gearwheels	tooth clutch (incl. synchroniser) or sliding gearwheel	200
drive shaft and/or more than 2 engaged gearwheels	multi-disc clutch	450
drive shaft and/or more than 2 engaged gearwheels	multi-disc clutch with dedicated pump for PTO clutch	3 100
PTO which includes 1 or more additional gearmesh(es), without disconnect clutch	—	1 500

In the case of multiple PTOs mounted to the transmission, only the component with the highest losses in accordance with Table 12, for its combination of criteria ‘PTOShaftsGearWheels’ and ‘PTOShaft-sOtherElements’, shall be declared. For medium lorries and heavy buses, no declaration of transmission PTOs is foreseen.

▼B

ANNEX X

CERTIFICATION PROCEDURE FOR PNEUMATIC TYRES

1. Introduction

This Annex describes the certification provisions for tyre with regard to its rolling resistance coefficient. For the calculation of the vehicle rolling resistance to be used as the simulation tool input, the applicable tyre rolling resistance coefficient C_r for each tyre supplied to the original equipment manufacturers and the related tyre test load F_{ZTYRE} shall be declared by the applicant for pneumatic tyre approval.

▼M3

2. Definitions

For the purposes of this Annex, in addition to the definitions contained in UN Regulation No. 54 [1] and in UN Regulation No. 117 [2], the following definitions shall apply:

▼B

(1) 'Rolling resistance coefficient C_r' means a ratio of the rolling resistance to the load on the tyre

(2) 'The load on the tyre F_{ZTYRE}' means a load applied to the tyre during the rolling resistance test.

(3) 'Type of tyre' means a range of tyres which do not differ in such characteristics as:

(a) Manufacturer's name;

(b) Brand name or trade mark ►M3 ; ◄

▼M3

(c) Tyre class (in accordance with UN Regulation No. 117);

▼B

(d) Tyre-size designation;

(e) Tyre structure (diagonal (bias-ply), radial);

(f) Category of use (normal tyre, snow tyre, special use tyre) as defined in ►M3 UN ◄ Regulation No.117;

(g) Speed category (categories);

(h) Load-capacity index (indices);

(i) Trade description/commercial name;

(j) Declared tyre rolling resistance coefficient

▼M3

(4) 'FuelEfficiencyClass' is a parameter corresponding to the fuel efficiency class of the tyre as defined in Regulation (EU) 2020/740 [3] Annex I, part A. For tyres which are not in the scope of Regulation (EU) 2020/740, the fuel efficiency class of the tyre is not applicable and parameter FuelEfficiencyClass shall be recorded in Appendix 3 as 'N/A'.

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(1) Regulation No 54 of the Economic Commission for Europe of the United Nations (UNECE) — Uniform provisions concerning the approval of pneumatic tyres for commercial vehicles and their trailers (OJ L 183, 11.7.2008, p. 41).

(2) Regulation No 117 of the Economic Commission for Europe of the United Nations (UNECE) — Uniform provisions concerning the approval of tyres with regard to rolling sound emissions and/or to adhesion on wet surfaces and/or to rolling resistance [2016/1350] (OJ L 218, 12.8.2016, p. 1).

(3) Regulation (EU) 2020/740 of the European Parliament and of the Council of 25 May 2020 on the labelling of tyres with respect to fuel efficiency and other parameters, amending Regulation (EU) 2017/1369 and repealing Regulation (EC) No 1222/2009 (OJ L 177, 5.6.2020, p. 1).

▼B

3. General requirements

3.1. The tyre manufacturer plant shall be certified to ►M3 IATF ◄ 16949.

▼M3

3.2. Tyre rolling resistance coefficient measurement

The tyre rolling resistance coefficient shall be measured and aligned in accordance with Regulation (EU) 2020/740 Annex I, part A, expressed in N/kN and rounded to the first decimal place, in accordance with ISO 80000-1 Appendix B, section B.3, rule B (example 1).

The standard rolling resistance coefficient value for C2 and C3 tyres shall be the one corresponding to snow tyres for use in severe snow conditions as set out in UN Regulation No. 117 paragraph 6.3.2. For tyres not in the scope of Regulation (EC) No 661/2009 ([53]) or Regulation (EU) 2019/2144 ([54]), the standard value shall be 13,0 N/kN and the FuelEfficiencyClass shall be stated as 'N/A'.

The standard FzISO value shall be the one obtained as a percentage of the vertical force related to tyre load index at nominal tyre pressure (and single tyre application). For C2 and C3 tyres this percentage shall be 85 %, for other tyres the percentage shall be 80 %.

3.3. Measurement provisions

The tyre manufacturer shall test either in a laboratory of technical services as defined in Article 68 of Regulation (EU) 2018/858 the test referred to in point 3.2, or in its own facilities in the case that:

(i) a representative of a technical service designated by the responsible approval authority supervises the test; or

(ii) the tyre manufacturer is designated as a technical service of Category A in accordance with Article 68 of Regulation (EU) 2018/858.

▼B

3.4. Marking and traceability

▼M3

3.4.1. The tyre shall be clearly identifiable in respect to the applicable certificate and the corresponding rolling resistance coefficient.

▼B

3.4.2. ►M1 The tyre manufacturer shall use the markings affixed to the side wall of the tyre or affix an additional identifier to the tyre. ◄ The additional identification shall ensure a unique link of the tyre and its rolling resistance coefficient. It may take a form of:

— quick response (QR) code,

— barcode,

— radio-frequency identification (RFID),

— an additional marking, or

— other tool fulfilling the requirements of 3.4.1.

3.4.3. If an additional identifier is used it shall remain readable until the moment of sales of the vehicle.

([53]) Regulation (EC) No 661/2009 of the European Parliament and of the Council of 13 July 2009 concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor (OJ L 200, 31.7.2009, p. 1).

([54]) Regulation (EU) 2019/2144 of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles and their trailers, and systems, components and separate technical units intended for such vehicles, as regards their general safety and the protection of vehicle occupants and vulnerable road users, amending Regulation (EU) 2018/858 of the European Parliament and of the Council (OJ L 325, 16.12.2019, p. 1)

▼B

3.4.4. ►M3 In line with Article 38(2) of Regulation (EU) 2018/858, no type-approval mark is required for tyres certified in accordance with this Regulation. ◄

4. Conformity of the certified CO_2 emissions and fuel consumption related properties

4.1. Any tyre certified under this Regulation shall be in conformity to the declared rolling resistance value as per paragraph 3.2 of this Annex.

4.2. In order to verify conformity of the certified CO_2 emissions and fuel consumption related properties, production samples shall be taken randomly from series production and tested in accordance with the provisions set out in paragraph 3.2. ►M3 The tests have to be performed on new test tyres in the sense of the definition set out in paragraph 2 of UN Regulation No. 117. ◄

4.3. Frequency of the tests

4.3.1 The tyre rolling resistance of at least one tyre of a specific type intended for the sales to the original equipment manufacturers shall be tested every 20 000 units of this type per year (e.g. 2 conformity verifications per year of the type whose annual sales volume to the original equipment manufacturers is between 20 001 and 40 000 units).

4.3.2 In case the deliveries of a specific tyre type intended for the sales to the original equipment manufacturers is between 500 and 20 000 units per year, at least one conformity verification of the type shall be carried out per year.

4.3.3 In case the deliveries of a specific tyre type intended for the sales to the original equipment manufacturers is below 500 units, at least one conformity verification as described in paragraph 4.4 shall be applied every second year.

4.3.4 If the volume of tyres delivered to the original equipment manufacturers indicated in 4.3.1 is met within 31 calendar days the maximum number of conformity verifications as described in paragraph 4.3 is limited to one per 31 calendar days.

4.3.5 The manufacturer shall justify (ex. by showing sales numbers) to the approval authority the number of tests which has been performed

4.4 Verification procedure

4.4.1 A single tyre shall be tested in accordance with paragraph 3.2. By default, the machine alignment equation shall be the one valid at the date of verification testing. ►M3 ———— ◄

▼M3

4.4.2 In the case that the measured and aligned value is lower or equal to the declared value plus 0,3 N/kN, the tyre rolling resistance value is considered compliant.

4.4.3 Where the measured and aligned value exceeds the declared value by more than 0,3 N/kN, the alignment equation that was valid at the time of the certification testing may be applied upon request of the tyre manufacturer and in agreement with the authority that is supervising the verification.

4.4.3.1 If the measured and realigned value is lower or equal to the declared value plus 0,3 N/kN, the tyre rolling resistance value is considered compliant.

4.4.3.2 If the measured value, aligned as per points 4.4.3 and 4.4.3.1, exceeds the declared value by more than 0,3 N/kN, three additional tyres shall be tested. If the measured value, aligned as per points 4.4.3 and 4.4.3.1, of at least one of the three tyres exceeds the declared value by more than 0,4 N/kN, Article 23 shall apply.

▼M1

Appendix 1

MODEL OF A CERTIFICATE OF A COMPONENT, SEPARATE TECHNICAL UNIT OR SYSTEM

Maximum format: A4 (210 × 297 mm)

CERTIFICATE ON CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF A TYRE FAMILY

Communication concerning:

Administration stamp

— granting [1]

— extension [1]

— refusal [1]

— withdrawal [1]

[1] 'delete as appropriate'

of a certificate on CO_2 emission and fuel consumption related properties of a tyre family in accordance with Commission Regulation (EU) 2017/2400, as amended by Commission Regulation (EU) 2019/318

Certification number: ....

Hash: ....

Reason for extension: ....

1. Manufacturer's name and address: ....

2. If applicable, name and address of manufacturer's representative: ....

3. Brand name/trade mark: ....

4. Tyre type description: ....

   (a) Manufacturer's name ....

   (b) Brand name or trade mark

▼M3

   (c) Tyre class (in accordance with Regulation (EC) No 661/2009 or Regulation (EU) 2019/2144)

▼M1

   (d) Tyre-size designation ....

   (e) Tyre structure (diagonal (bias-ply); radial) ....

   (f) Category of use (normal tyre, snow tyre, special use tyre) ....

   (g) Speed category (categories) ....

   (h) Load-capacity index (indices) ....

   (i) Trade description/commercial name ....

   (j) Declared tyre rolling resistance coefficient ....

5. Tyre identification code(s) and technology(ies) used to provide identification code(s), if applicable:

Technology:	Code:
…	…

6. Technical Service and, where appropriate, test laboratory approved for purposes of approval or of verification of conformity tests: ....

▼**M1**

7. Declared values:

7.1. declared rolling resistance level of the tyre (in N/kN rounded to the first decimal place, in accordance with ISO 80000-1 Appendix B, section B.3, rule B (*example 1*))

Cr, ... [N/kN]

▼**M3**

7.2. tyre test load in accordance with Regulation (EU) 2020/740, Annex I, part A

F_{ZTYRE}..[N]

▼**M1**

7.3. Alignment equation: ....

8. Any remarks: ....

9. Place: …

10. Date: …

11. Signature: ....

12. Annexed to this communication are: ....

▼B

Appendix 2

Tyre rolling resistance coefficient information document

SECTION I

0.1 Name and address of manufacturer;

▼M3

0.2 Brand name(s)/trademark(s);

▼B

0.3 Name and address of applicant:

▼M3

0.4 Trade description(s)/commercial name(s);

0.5 Tyre class (in accordance with UN Regulation No. 117);

▼B

0.6 Tyre-size designation;

0.7 Tyre structure (diagonal (bias-ply); radial);

0.8 Category of use (normal tyre, snow tyre, special use tyre);

0.9 Speed category (categories);

0.10 Load-capacity index (indices);

▼M3

0.11 -

▼B

0.12 Declared rolling resistance coefficient;

0.13 Tool(s) to provide additional rolling resistance coefficient identification code (if any);

▼M1

————

▼B

0.15 Load F_{ZTYRE}: .... [N]

▼M1

————

▼M3

0.16 Tyre Type Approval Marking (in accordance with UN Regulation No. 117), if applicable;

0.17 Tyre Type Approval Marking (in accordance with UN Regulation No. 54 or 30 ([1])

▼B

SECTION II

1. Approval Authority or Technical Service [or Accredited Lab]:

2. Test report No.:

3. Comments (if any):

▼M1

4. Date of test report:

▼B

5. Test machine identification and drum diameter/surface:

6. Test tyre details:

6.1. Tyre size designation and service description:

([1]) Regulation No 30 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of pneumatic tyres for motor vehicles and their trailers (OJ L 201, 30.7.2008, p. 70).

▼B

6.2. Tyre brand/ trade description:

▼M3

6.3. Reference test inflation pressure: kPa

▼B

7. Test data:

7.1. Measurement method:

7.2. Test speed: km/h

7.3. Load F_{ZTYRE}: N

7.4. Test inflation pressure, initial: kPa

7.5. Distance from the tyre axis to the drum outer surface under steady state conditions, r_L: m

7.6. Test rim width and material:

7.7. Ambient temperature: °C

7.8. Skim test load (except deceleration method): N

8. Rolling resistance coefficient:

▼M3

8.1. Initial value (or average in the case there is more than one): N/kN

▼B

8.2. Temperature corrected: .... N/kN

8.3. Temperature and drum diameter corrected: N/kN

▼M1

8.4. Alignment equation:

8.5. Rolling resistance level of the tyre (in N/kN rounded to the first decimal place, in accordance with ISO80000-1 Appendix B, section B.3, rule B (example 1)) $C_{r,aligned}$: .... [N/kN]

▼B

9. Date of test:

▼B

Appendix 3

▼M1

Input parameters for the simulation tool

▼B

Introduction

This Appendix describes the list of parameters to be provided by the component manufacturer as input to the simulation tool. The applicable XML schema as well as example data are available at the dedicated electronic distribution platform.

Definitions

▼M1

(1) 'Parameter ID': Unique identifier as used in the simulation tool for a specific input parameter or set of input data

▼B

(2) 'Type': Data type of the parameter

string .... sequence of characters in ISO8859-1 encoding

token .... sequence of characters in ISO8859-1 encoding, no leading/trailing whitespace

date .... date and time in UTC time in the format: YYYY-MM-DD***T***HH:MM:SS***Z*** with italic letters denoting fixed characters e.g. '2002-05-30T09:30:10Z'

integer .... value with an integral data type, no leading zeros, e.g. '1800'

double, X .... fractional number with exactly X digits after the decimal sign ('.') and no leading zeros e.g. for 'double, 2': '2345.67'; for 'double, 4': '45.6780'

(3) 'Unit' … physical unit of the parameter

Set of input parameters

Table 1

Input parameters 'Tyre'

Parameter name	Param ID	Type	Unit	Description/Reference
Manufacturer	P230	token		
Model	P231	token		Trade name of manufacturer
▼M1 Certification-Number	P232	token		
▼B Date	P233	date		Date and time when the component hash is created.

▼B

Parameter name	Param ID	Type	Unit	Description/Reference
AppVersion	P234	token		Version number identifying the evaluation tool
RRCDeclared	P046	double, 4	[N/N]	
FzISO	P047	integer	[N]	
▼M1				
►M3 Tyre Size Designation ◄	P108	string	[-]	Allowed values (non-exhaustive): '9.00 R20', '9 R22.5', '9.5 R17.5', '10 R17.5', '10 R22.5', '10.00 R20', '11 R22.5', '11.00 R20', '11.00 R22.5', '12 R22.5', '12.00 R20', '12.00 R24', '12.5 R20', '13 R22.5', '14.00 R20', '14.5 R20', '16.00 R20', '205/75 R17.5', '215/75 R17.5', '225/70 R17.5', '225/75 R17.5', '235/75 R17.5', '245/70 R17.5', '245/70 R19.5', '255/70 R22.5', '265/70 R17.5', '265/70 R19.5', '275/70 R22.5', '275/80 R22.5', '285/60 R22.5', '285/70 R19.5', '295/55 R22.5', '295/60 R22.5', '295/80 R22.5', '305/60 R22.5', '305/70 R19.5', '305/70 R22.5', '305/75 R24.5', '315/45 R22.5', '315/60 R22.5', '315/70 R22.5', '315/80 R22.5', '325/95 R24', '335/80 R20', '355/50 R22.5', '365/70 R22.5', '365/80 R20', '365/85 R20', '375/45 R22.5', '375/50 R22.5', '375/90 R22.5', '385/55 R22.5', '385/65 R22.5', '395/85 R20', '425/65 R22.5', '495/45 R22.5', '525/65 R20.5'
▼M3				
TyreClass	P370	string	[-]	'C2', 'C3' or 'N/A'
FuelEfficiency-Class	P371	string		'A', 'B', 'C', 'D', 'E' or 'N/A'

▼B

Appendix 4

Numbering

1. Numbering:

▼M3

1.1 Certification number for tyres shall comprise the following:

eX*YYYY/YYYY*ZZZZ/ZZZZ*T*00000*00

section 1	section 2	section 3	Additional letter to section 3	section 4	section 5
Indication of country issuing the certificate	HDV CO_2 determination Regulation ‘2017/2400’	Latest amending Regulation (ZZZZ/ZZZZ)	T = Tyre	Base certification number 00000	Extension 00

▼M3

ANNEX Xa

CONFORMITY OF SIMULATION TOOL OPERATION AND OF CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF COMPONENTS, SEPARATE TECHNICAL UNITS AND SYSTEMS: VERIFICATION TESTING PROCEDURE

1. Introduction

This Annex sets out the requirements for the verification testing procedure, which is the test procedure for verifying the CO_2 emissions of new medium and heavy lorries.

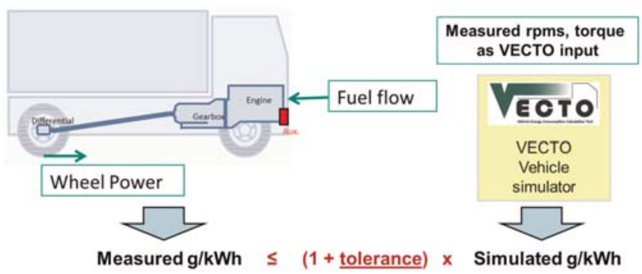
The verification testing procedure consists of an on-road test to verify the CO_2 emissions of new vehicles after production. It shall be carried out by the vehicle manufacturer and supervised by the approval authority that granted the licence to operate the simulation tool.

During the verification testing procedure the torque and speed at the driven wheels, the engine speed, the fuel consumption, the engaged gear of the vehicle and the other relevant parameters listed in point 6.1.6 shall be measured. The measured data shall be used as input to the simulation tool, which uses the vehicle-related input data and the input information from the determination of the CO_2 emissions and fuel consumption of the vehicle. For the verification testing procedure simulation, the instantaneously measured wheel torque and the rotational speed of the wheels as well as the engine speed shall be used as input. To pass the verification testing procedure the CO_2 emissions calculated from the measured fuel consumption shall be within the tolerances set out in point 7 compared to the CO_2 emissions from the verification testing procedure simulation. Figure 1 gives a schematic picture of the verification testing procedure method. The evaluation steps as performed by the simulation tool in the verification testing procedure simulation are described in Appendix 1 of this Annex.

As part of the verification testing procedure, the correctness of the vehicle input data set from the certification of CO_2 emissions and fuel consumption related properties of the components, separate technical units and systems shall also be reviewed to check the data and the data handling process. The correctness of the input data relating to components, separate technical units and systems relevant for air drag and for rolling resistance of the vehicle shall be verified in accordance with point 6.1.1.

Figure 1

Schematic picture of the verification testing procedure method



▼M3

2. Definitions

For the purposes of this Annex the following definitions shall apply:

(1) 'verification test relevant data set' means a set of input data for components, separate technical units and systems and input information used for CO_2 determination of a verification testing procedure relevant vehicle;

(2) 'verification testing procedure relevant vehicle' means a new vehicle for which a value of CO_2 emissions and fuel consumption was determined and declared in accordance with Article 9;

(3) 'corrected actual mass of the vehicle' means the 'corrected actual mass of the vehicle' as defined in Annex III, point 2(4);

(4) 'actual mass of the vehicle for VTP' is the actual mass of the vehicle as defined in Article 2(6) of Regulation (EU) No 1230/2012, but with a full-tank and plus the additional measurement equipment as set out in point 5 (measurement equipment), plus the actual mass of the trailer or semitrailer if demanded by 6.1.4.1;

(5) 'actual mass of the vehicle for VTP with payload' means the actual mass of the vehicle for VTP with the payload applied in the verification testing procedure as set out in 6.1.4.2;

(6) 'wheel power' means the total power at the driven wheels of a vehicle to overcome all driving resistances at the wheel, computed in the simulation tool from the measured torque and rotational speed of the driven wheels;

(7) 'controller area network signal' or 'CAN signal' means a signal from the connection with the vehicle electronic control unit as referred to in point 2.1.5 of Appendix 1 to Annex II to Regulation (EU) No 582/2011;

(8) 'urban driving' means the total distance driven during the fuel consumption measurement at speeds not exceeding 50 km/h;

(9) 'rural driving' means the total distance driven during the fuel consumption measurement at speeds exceeding 50 km/h, but not exceeding 70 km/h;

(10) 'motorway driving' means the total distance driven in the fuel consumption measurement at speeds above 70 km/h;

(11) 'crosstalk' means the signal at the main output of a sensor (M_y), produced by a measurand (F_z) acting on the sensor, which is different from the measurand assigned to this output; the coordinate system assignment is defined in accordance with ISO 4130.

3. Vehicle selection

The number of new vehicles to be tested per year of production ensures that the relevant variations of components, separate technical units or systems used are covered by the verification testing procedure. The vehicle selection for the verification test shall be based on the following requirements:

▼**M3**

(a) The vehicles for the verification test shall be selected out of the vehicles from the production line for which a value of CO_2 emissions and fuel consumption has been determined and declared in accordance with Article 9. The components, separate technical units or systems mounted in or on the vehicle shall be out of series production and shall correspond to those mounted at production date of the vehicle.

(b) The vehicle selection shall be made by the approval authority that granted the licence to operate the simulation tool based on proposals from the vehicle manufacturer.

(c) Only vehicles with one driven axle shall be selected for verification test.

(d) It is recommended to include in each verification test relevant data sets of the components of interest and with the highest sales numbers per manufacturer. The components, separate technical units or systems may be verified all in one vehicle or in different vehicles. Apart from the criterion of highest sales numbers, the approval authority mentioned in (b) shall decide whether other vehicles with relevant data sets engine, axle and transmission shall be included in the verification test.

(e) Vehicles which use standard values for CO_2 certification of their components, separate technical units or systems instead of measured values for the transmission and for the axle losses shall not be selected for the verification test as long as vehicles complying with the requirements in points (a) to (c) and using measured loss maps for these components, separate technical units or systems in the CO_2 certification, are produced.

(f) The minimum number of different vehicles with different combinations of verification test relevant data sets to be tested by verification test per year shall be based on the sales numbers of the vehicle manufacturer as set out in Table 1.

Table 1

Determination of the minimum number of vehicles to be tested by the vehicle manufacturer

Number of vehicles to be tested	Schedule	Verification testing procedure relevant vehicles produced / year (**)
0	—	≤ 25
1	every 3 years (*)	26 – 250
1	every 2 years	251 – 5 000
1	every year	5 001 – 25 000
2	every year	25 001 – 50 000
3	every year	50 001 – 75 000

▼M3

Number of vehicles to be tested	Schedule	Verification testing procedure relevant vehicles produced / year (**)
4	every year	75 001 – 100 000
5	every year	more than 100 000

(*) The total of all vehicles by a manufacturer falling within the scope of this regulation is to be considered and both medium lorries as well as heavy lorries need to be covered by the VTP over a six-year time span.
(**) The VTP shall be performed within the first two years.

(g) The vehicle manufacturer shall finalize the verification test within a period of 10 months after the date of selection of the vehicle for the verification test.

4. Vehicle conditions

Each vehicle for the verification test shall be in the condition resembling its intended placing on the market. No changes in hardware such as lubricants or in the software such as auxiliary controllers are allowed. The tyres may be replaced by measurement tyres of similar size (± 10 %).

The provisions as set out in points 3.3 to 3.6 of Annex II to Regulation (EU) 582/2011 shall apply.

4.1 Vehicle run in

Run in of the vehicle is not mandatory. If the total mileage of the test vehicle is less than 15 000 km, an evolution coefficient for the test result is applied by the simulation tool as defined in Appendix 1. The total mileage of the test vehicle shall be the odometer reading at start of the fuel consumption measurement. The maximum mileage at start of the warm-up shall be 20 000 km.

4.2 Fuel and lubricants

All lubricants shall be the same as the lubricants used when placing the vehicle on the market.

For the fuel consumption measurement as described in point 6.1.5 the fuel used shall be the one available on the market. In any case of dispute the fuel shall be the appropriate reference fuel specified in Annex IX to Regulation (EU) No 582/2011.

The fuel tank shall be full at start of the vehicle warm up. Refuelling of the vehicle between start of warm up and end of fuel consumption measurement is not allowed.

The net calorific value (NCV) of the fuel used in the verification test shall be determined in accordance with point 3.2 of Annex V. The fuel batch shall be taken from the tank after vehicle warm-up. In the case of dual-fuel engines, this procedure shall be applied to both fuels.

5. Measurement equipment

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

▼**M3**

5.1 Wheel torque

The direct torque at all driven axles shall be measured with one of the following measurement systems fulfilling the requirements listed in Table 2:

(a) hub torque meter;

(b) rim torque meter;

(c) half-shaft torque meter.

The drift shall be measured during the verification test by zeroing the torque measurement system in accordance with point 6.1.5.4 after the vehicle warm up in accordance with point 6.1.5.3. by lifting the axle and measuring the torque at lifted axle directly after the verification test again in accordance with point 6.1.5.6.

For a valid test result a maximum drift (sum of absolute values of both wheels) of the torque measurement system over the verification testing procedure of 1,5 % of the calibrated range of a single torque meter shall be proven.

5.2 Vehicle speed

The recorded vehicle speed shall be based on the CAN signal.

5.3 Gear engaged

For vehicles with SMT and AMT transmissions the engaged gear is calculated by the simulation tool based on measured engine speed, the vehicle speed and the tyre dimensions and transmission ratios of the vehicle in accordance with Appendix 1. The engine speed is taken by the simulation tool from the input data as defined in point 5.4.

For vehicles with APT transmissions the engaged gear as well as the status of the torque converter (active or not active) shall be provided from CAN signals.

5.4 Rotational speed of the engine

The rotational speed of the engine shall be recorded from the CAN, OBD or alternative measurement systems that fulfil the requirements set out in Table 2.

5.5 Rotational speed of the wheels at the driven axle

The rotational speed of the left and right wheel of the driven axle shall be recorded from the CAN or alternative measurement systems that fulfil the requirements set out in Table 2.

5.6 Rotational speed of fan

For non-electrically driven engine cooling fans the rotational speed of the fan shall be recorded. For this purpose either the CAN signal or alternatively an external sensor fulfilling the requirements set out in Table 2 shall be used.

For electrically driven engine cooling fans the current and voltage shall be recorded for the direct current input at the terminal of the electric motor or the inverter. From these two signals, the electrical power at the terminal shall be calculated by multiplication and shall be available as a time-resolved signal as input to the simulation tool. In the case of multiple electrically driven engine cooling fans, the sum of electrical power at the terminals shall be made available.

▼M3

5.7 Fuel measurement system

The fuel consumed shall be measured on-board with a measurement device based on one of the following measurement methods:

— Measurement of fuel mass. The fuel measuring device shall fulfil the accuracy requirements set out in Table 2 for the fuel mass measurement system.

— Measurement of fuel volume together with correction for the thermal expansion of the fuel. The fuel volume measurement device and fuel temperature measurement device shall fulfil the accuracy requirements set out in Table 2 for the fuel volume measurement system. Measured values of fuel volume flow shall be converted to fuel mass flow in accordance with the following equations:

$$m_{fuel,i} = V_{fuel,i} \cdot \rho_i$$

$$\rho_i = \frac{\rho_0}{1 + \beta(t_{i+1} - t_0)}$$

where:

$m_{fuel,\ i}$ = Fuel mass flow at sample i [g/h]

ρ_0 = Density of the fuel used for the verification test in (g/dm^3). The density shall be determined in accordance with Annex IX to the Regulation (EU) No 582/2011. If diesel fuel is used in the verification test, also the average value of the density interval for the reference fuels B7 in accordance with Annex IX to the Regulation (EU) No 582/2011 may be used.

t_0 = Fuel temperature that corresponds to density ρ_0 for the reference fuel [°C]

ρ_i = Density of the test fuel at sample i [g/dm^3]

$V_{fuel,\ i}$ = Fuel volume flow at sample i [dm^3/h]

t_i = Measured fuel temperature at sample i [°C]

β = Temperature correction factor (0,001 K^{-1}).

For dual-fuel vehicles the fuel flow shall be measured for each of the two fuels separately.

5.8 Vehicle mass

The following masses of the vehicle shall be measured with equipment fulfilling the requirements set out in Table 2:

(a) actual mass of the vehicle for VTP;

(b) actual mass of the vehicle for VTP with payload.

5.9 General requirements for the on-board measurements as specified under 5.1 to 5.8

The input data as set out in point 6.1.6. Table 4 shall be provided from the measurements. All data shall be recorded at least in 2 Hz frequency or at recommended frequency from the equipment maker, whichever is the higher value.

▼M3

The input data for the simulation tool may be composed from different recorders. The torque and rotational speed at the wheels shall be recorded in one data-logging system. If different data-logging systems are used for the other signals, one common signal, such as vehicle speed, shall be recorded to ensure correct time alignment of the signals. The time alignment of the signals shall result in the highest correlation coefficient of the common signal recorded with the different data loggers.

The accuracy requirements set out in Table 2 shall be met by all measurement equipment used. Any equipment not listed in Table 2 shall fulfil the accuracy requirements set out in Table 2 of Annex V.

Table 2

Requirements of measurement systems

Measurement system	Accuracy	Rise time (1)
Balance for vehicle weight	50 kg or < 0,5 % of max. calibration whichever is smaller	—
Rotational speed wheels	< 0,5 % of reading at 80 km/h	≤ 1 s
Fuel mass flow for liquid fuels (2)	< 1,0 % of reading or < 0,2 % of max. calibration whichever is larger	—
Fuel mass flow for gaseous fuels (2)	< 1,0 % of reading or < 0,5 % of max. calibration whichever is larger	—
Fuel volume measurement system (2)	< 1,0 % of reading or < 0,5 % of max. calibration whichever is larger	—
Temperature of the fuel	± 1 °C	≤ 2 s
Sensor for measuring the rotational speed cooling fan	< 0,4 % of reading or < 0,2 % of max. calibration of speed whichever is larger	≤ 1 s
Voltage	< 2 % of reading or < 1 % of max. calibration of speed whichever is larger	≤ 1 s
Current	< 2 % of reading or < 1 % of max. calibration of speed whichever is larger	≤ 1 s
Engine speed	As set out in Annex V. In the case of vehicles with engine stop-start, it shall be verified that the engine speed is also recorded correctly for speeds below idle.	

▼M3

Measurement system	Accuracy	Rise time [1]
Wheel torque	For 10 kNm calibration (over the entire calibration range): i. Non linearity [3]: < ± 40 Nm for heavy lorries < ± 30 Nm for medium lorries ii. Repeatability [4]: < ± 20 Nm for heavy lorries < ± 15 Nm for medium lorries iii. Crosstalk: < ± 20 Nm for heavy lorries < ± 15 Nm for medium lorries (only applicable for rim torque meters) iv. Measurement rate: ≥ 20 Hz	< 0,1 s

(1) Rise time means the difference in time between the 10 % and 90 % response of the final analyser reading (t90 – t10).
(2) The accuracy shall be met for the integral fuel flow over 100 minutes.
(3) Non linearity means the maximum deviation between ideal and actual output signal characteristics in relation to the measured value in a specific measuring range.
(4) Repeatability means closeness of the agreement between the results of successive measurements of the same measured value carried out under the same conditions of measurement.

The maximum calibration values shall be the maximum expected values during all test runs for the respective measurement system, multiplied by an arbitrary factor larger than 1 and less or equal than 2. For the torque measurement system the maximum calibration may be limited to 10 kNm.

In the case of dual-fuel engines, the maximum calibration value for the measurement system for fuel mass flow or fuel volume shall be determined following the requirements laid down in point 3.5 of Annex V. For fuel volume the maximum calibration value shall be determined by dividing the maximum calibration values for fuel mass flow by the density value ρ_0 defined in accordance with point 5.7.

Accuracy given shall be met by the sum of all single accuracies in the case more than one scale is used.

5.10. Engine torque

The engine torque shall be recorded during the verification testing procedure for the purpose of evaluating pollutant emissions. The signal shall fulfil the provisions as specified for the engine torque signal in Table 1 of point 2.2 of Appendix 1 to Annex II to Regulation (EU) 582/2011.

5.11. Pollutant emissions

For measurement of pollutant emissions the instrumentation and procedures as set out in Appendices 1 to 4 of Annex II to Regulation (EU) 582/2011 shall be used. The data evaluation shall provide instantaneous emission mass flows as set out in Table 4 of point 6.1.6. as input to the simulation tool.

Based on these input signals the simulation tool automatically calculates the brake specific pollutant emissions measured in the verification test (BSEM) as set out in Part B of Appendix 1 of this Annex. These results are then automatically written into the output of the simulation tool according to point 8.13.14. The additional requirements set out in Regulation (EU) 582/2011 on data evaluation (e.g. work based windows, moving average windows), test start and trip shall not apply.

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In the verification test procedure, pass/fail criteria regarding pollutant emissions shall not apply.

6. Test procedure

6.1 Vehicle preparation

The vehicle shall be taken from the series production and selected as set out in point 3.

6.1.1 Verification of input information and input data and data handling

The manufacturer's records file and the customer information file for the vehicle selected shall be used as basis for verifying the input data. The vehicle identification number of the vehicle selected shall be the same as the vehicle identification number in the manufacturer's records file and the customer information file.

Upon request by the approval authority that granted the licence to operate the simulation tool, the vehicle manufacturer shall provide, within 15 working days, the manufacturer's records file, the input information and input data necessary to run the simulation tool as well as the certificate of CO_2 emissions and fuel consumption related properties for all relevant components, separate technical units or systems.

6.1.1.1 Verification of components, separate technical units or systems and input data and information

The following checks shall be performed for the components, separate technical units and systems mounted on the vehicle:

(a) Simulation tool data integrity: the integrity of the cryptographic hash of the manufacturer’s records file in accordance with Article 9(3) re-calculated during the verification testing procedure with the hashing tool shall be verified by comparison with the cryptographic hash in the certificate of conformity;

(b) Vehicle data: the vehicle identification number, axle configuration, selected auxiliaries and power take off technology, disabled gears in accordance with point 6.2 of Annex III and requirements on active aero devices as set out in point 3.3.1.5 of Annex VIII shall match the selected vehicle;

(c) Engine torque limitations declared in the input to the simulation tool are subject to a verification in the VTP if they are declared for any of the highest 50 % of the gears (e.g. for any of the gears 7 to 12 of a 12-gear transmission) and if one of the following cases shall apply:

(i) Torque limit declared on the vehicle level in accordance with point 6.1 of Annex III

(ii) Torque limit declared in the input to the transmission component in accordance with parameter P157 in Table 2 of Appendix 12 of Annex VI and if the declared value does not exceed 90 % of the engine maximum torque

For any of the torque limits subject to a verification it shall be demonstrated that the 99 % percentile of the engine torque recorded during the fuel consumption measurement in the relevant gear does not exceed the declared torque limit by more than 5 %. For this purpose the verification test shall cover phases of full throttle in the respective gears. The verification shall be performed based on recorded engine torque as set out in 5.10.

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The engine torque limitation verification may also be performed as a separate test only, consisting of dedicated full-load accelerations and with no other obligations on test evaluation.

(d) Component, separate technical unit or system data: the certification number and the model type imprinted on the certificate of CO_2 emissions and fuel consumption related properties shall match the component, separate technical unit or system installed in the selected vehicle;

(e) The hash of the simulation tool input data and the input information shall match the hash imprinted on the certificate of CO_2 emissions and fuel consumption related properties for the following components, separate technical units or systems:

(i) engines;

(ii) transmissions;

(iii) torque converters;

(iv) other torque transferring components;

(v) additional drivetrain components;

(vi) axles;

(vii) body or trailer air drag;

(viii) tyres.

6.1.1.2 Verification of the vehicle mass

If requested by the approval authority that granted the licence to operate the simulation tool, the determination of masses by the manufacturer shall be verified in accordance with point 2 of Appendix 2 of Annex I to Regulation (EU) No 1230/2012. Where that verification fails, the corrected actual mass as defined in point 2(4) of Annex III to this Regulation shall be determined.

6.1.1.3 Actions to be taken

In the case of discrepancies in the certification number or the cryptographic hash of one or more files regarding the components, separate technical units or systems listed in subpoints (1) to (8) of point 6.1.1.1 (e) the correct input data file fulfilling the checks in accordance with points 6.1.1.1 and 6.1.1.2 shall replace the incorrect data for all further actions. The same applies to any other incorrect information identified in subpoints (b) and (c) of point 6.1.1.1.

If the verification of results in the manufacturer's records file and the customer information file fails or no complete input data set with correct certificates of CO_2 emissions and fuel consumption related properties is available for the components, separate technical units or systems listed in subpoints (1) to (8) of point 6.1.1.1 (e) the verification test shall end and the vehicle fails the verification testing procedure.

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6.1.2 Run in phase

A run in phase up to maximum 15 000 km odometer reading may take place. In the case of damage of any of the components, separate technical units or systems listed in point 6.1.1.1, the component, separate technical units or systems may be replaced by an equivalent component, separate technical units or systems with the same certification number. The replacement shall be documented in the test report.

All relevant components, separate technical units or systems shall be checked before the measurements to exclude unusual conditions, such as incorrect oil fill levels, plugged air filters or on-board diagnostic warnings.

6.1.3 Set up of measurement equipment

All measurement systems shall be calibrated in accordance with the provisions of the equipment maker. If no provisions exist, the recommendations from the equipment maker shall be followed for calibration.

After the run in phase, the vehicle shall be equipped with the measurement systems set out in point 5.

6.1.4 Set up of the test vehicle for the fuel consumption measurement

6.1.4.1 Vehicle configuration

Tractors of the vehicle groups defined in Table 1 and 2 of Annex I shall be tested with any type of semitrailer, providing the payload defined below can be applied.

Rigid lorries of the vehicle groups defined in Table 1 and 2 of Annex I shall be tested with trailer, if a trailer connection is mounted. Any body type or other device to carry the payload set out in point 6.1.4.2 can be applied. The bodies of rigid lorries may differ from the standard bodies set out in Appendix 4, point 2, of Annex VIII.

Vans of the vehicle groups defined in Table 2 of Annex I shall be tested with the final bodies of the complete or completed vehicle.

6.1.4.2 Vehicle payload

For heavy lorries of groups 4 and higher numbers the vehicle payload shall be set at minimum to a mass leading to a total test weight of 90 % of the maximum authorised weight in accordance with 96/53/EC (*) for the specific vehicle or vehicle combination.

For heavy lorries of groups 1s, 1, 2 and 3, and medium lorries the payload shall be in the range of 55 % to 75 % of the maximum authorised weight in accordance with 96/53/EC for the specific vehicle or vehicle combination.

6.1.4.3 Tyre inflation pressure

The tyre inflation pressure shall be set to the recommendation of the manufacturer with a maximum deviation of less than 10 %. The tyres of the semitrailer may differ from the standard tyres set out in Table 2 of Part B of Annex II to Regulation (EC) No 661/2009 for the CO_2 certification of tyres.

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6.1.4.4 Settings for auxiliaries

All settings influencing the auxiliary energy demand shall be set to minimum reasonable energy consumption where applicable. The air conditioning shall be switched off and venting of the cabin shall be set lower than medium mass flow. Additional energy consumers not necessary to run the vehicle shall be switched off. External devices to provide energy on board, such as external batteries, are allowed only for running the extra measurement equipment for the verification testing procedure listed in Table 2, but shall not provide energy to vehicle equipment that will be present when placing the vehicle on the market.

6.1.4.5 Particle filter regeneration

A particle filter regeneration shall, if applicable, be initiated before the verification test. Regulation (EU) 582/2011, Annex II, point 4.6.10 shall apply.

6.1.5 Verification test

6.1.5.1 Route selection

The route selected for the verification test shall fulfil the requirements set out in Table 3. The routes may include both public and private tracks.

6.1.5.2 Vehicle pre conditioning

No other pre-conditioning is allowed than the pre-condition in accordance with point 6.1.5.3.

6.1.5.3 Vehicle warm up

Before the fuel consumption measurement starts, the vehicle shall be driven for warm up as set out in Table 3. The warm up phase shall not be considered in the evaluation of the verification test.

Before warm up is started, the PEMS analysers shall be checked and calibrated in accordance with the procedures as set out in Appendix 1 of Annex II to Regulation (EU) 582/2011.

6.1.5.4 Zeroing of the torque measurement equipment

The zeroing of the torque meters shall be performed as follows:

— Bring the vehicle to a standstill;

— Lift the instrumented wheels off the ground, in such a way that the wheels are able to rotate freely and no external torque is applied to the torque sensor;

— Perform the zeroing of the amplifier reading of the torque meters. Zeroing shall be finished within less than 20 minutes.

6.1.5.5 Fuel consumption measurement and recording of pollutant emission signals

The fuel consumption measurement shall start directly after the zeroing of the wheel-torque measurement equipment at vehicle stand still. The vehicle shall be driven during the measurement in a driving style avoiding unnecessary braking of the vehicle, gas pedal pumping and aggressive cornering. The setting for the advanced driver assistance systems which is activated automatically at key-on shall be used, and gear shifts shall be performed by the automated system (in the case of AMT or APT transmissions) and the cruise control shall be used (if applicable). The duration of the fuel consumption measurement shall be within the tolerances set out in Table 3. The fuel consumption measurement shall end also at vehicle stand still directly before the measurement of the drift of the torque measurement equipment.

▼**M3**

The recording of signals relevant for the evaluation of pollutant emissions shall start latest once the fuel consumption measurement has started and end together with the fuel consumption measurement.

As input to the simulation tool the entire test sequence, starting with the last 0,5 s time step of the standstill phase after the zeroing of torque meters and ending with the first 0,5 s time step of the final standstill phase, shall be provided.

6.1.5.6 Measurement of the drift of the torque measurement equipment

Directly after the fuel consumption measurement, the drift of the torque measurement equipment shall be recorded by measuring the torque at the same vehicle conditions as during the zeroing process. If the fuel consumption measurement does end before the stop for the drift measurement, the vehicle shall be stopped for the drift measurement within 5 minutes. The drift of each torque meter shall be calculated from the average of a minimum sequence of 10 seconds.

Directly thereafter, the verification of the emission measurements shall be performed in accordance with the procedures as set out in point 2.7 of Appendix 1 to Annex II to Regulation (EU) 582/2011.

6.1.5.7 Boundary conditions for the verification test

The boundary conditions to be met for a valid verification test are set in Tables 3 to 3b.

If the vehicle passes the verification test in accordance with point 7.3, the test shall be set valid even if the following conditions are not met:

— undercut of minimum values for parameter No 1, 2, 6 and 9;

— exceedance of maximum values for parameter No 3, 4, 5, 7, 8, 10 and 12;

— exceedance of maximum values for parameter No 7, if the total testing time which is not in standstill exceeds 80 minutes.

Table 3

Parameters for a valid verification test for all vehicle groups

No.	Parameter	Min.	Max.
1	Warm up [minutes]	60	
2	Average velocity at warm up [km/h]	70 [1]	100
3	Fuel consumption measurement duration [minutes]	80	120
8	Average ambient temperature	5°C	30 C
9	Road condition dry	100 %	
10	Road condition snow or ice		0 %

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No.	Parameter	Min.	Max.
11	Sea level of the route [m]		800
12	Duration of continuous idling at stand still [minutes]		3

([1]) Where the maximum vehicle speed is less than 80 km/h, the average velocity in the warm-up shall exceed maximum vehicle speed minus 10 km/h.

Table 3a

Parameters for a valid verification test for vehicle groups 4, 5, 9, 10

No.	Parameter	Min.	Max.
4	Distance based share urban driving	2 %	8 %
5	Distance based share rural driving	7 %	13 %
6	Distance based share motorway driving	79 %	—
7	Time share of idling at stand still		5 %

Table 3b

Parameters for a valid verification test for other heavy and medium lorries

No.	Parameter	Min.	Max.
4	Distance based share urban driving	10 %	50 %
5	Distance based share rural driving	15 %	25 %
6	Distance based share motorway driving	25 %	—
7	Time share of idling at stand still		10 %

In the event of extraordinary traffic conditions the verification test shall be repeated.

6.1.6 Data reporting

The data recorded during the verification testing procedure shall be reported to the approval authority that granted the licence to operate the simulation tool as follows:

The data recorded shall be reported in a constant 2 Hz signals as set out in Table 4. The data recorded at higher frequencies than 2 Hz shall be converted into 2 Hz by averaging the time intervals around the 2 Hz nodes. In the case of e.g. 10 Hz sampling, the first 2 Hz

▼**M3**

node is defined by the average from second 0,1 to 0,5, the second node is defined by the average from second 0,6 to 1,0. The time stamp for each node shall be the last time stamp per node, i.e. 0,5, 1,0, 1,5 etc.

Table 4

Data reporting format for measured data for the simulation tool in the verification test

Quantity	Unit	Heading input data	Comment
time node	[s]	<t>	
vehicle speed	[km/h]	<v>	
engine speed	[rpm]	<n_eng>	
engine cooling fan speed	[rpm]	<n_fan>	In the case of non-electrically driven engine cooling fans
engine cooling fan electrical power	[W]	<Pel_fan>	In the case of electrically driven engine cooling fans
torque left wheel	[Nm]	<tq_wh_left>	
torque right wheel	[Nm]	<tq_wh_right>	
wheel speed left	[rpm]	<n_wh_left>	
wheel speed right	[rpm]	<n_wh_right>	
gear	[-]	<gear>	mandatory for APT transmissions
Torque converter active	[-]	<TC_active>	0 = not active (locked); 1 = active (unlocked); mandatory for AT transmissions, not relevant for other transmission types
fuel flow	[g/h]	<fc_*X*>	Fuel mass flow in accordance with point 5.7 ([1]). In the heading '*X*' shall be the fuel type in accordance with Table 2 of Appendix 7 of Annex V to this Regulation, e.g. '<fc_Diesel CI>'. For dual-fuel engines a separate column for each fuel shall be provided.
Engine torque	[Nm]	<tq_eng>	Engine torque in accordance with point 5.10.
CH_4 mass flow	[g/s]	<CH4>	Only if this component needs to be measured in accordance with point 1 of Appendix 1 of Annex II to Regulation (EU) 582/2011

▼M3

Quantity	Unit	Heading input data	Comment
CO mass flow	[g/s]	<CO>	
NMHC mass flow	[g/s]	<NMHC>	Only if this component needs to be measured in accordance with point 1 of Appendix 1 of Annex II to Regulation (EU) 582/2011
NO_x mass flow	[g/s]	<NOx>	
THC mass flow	[g/s]	<THC>	Only if this component needs to be measured in accordance with point 1 of Appendix 1 of Annex II to Regulation (EU) 582/2011
PM number flow	[#/s]	<PN>	
CO_2 mass flow	[g/s]		

(1) The correction of fuel flow to standard NCV is performed automatically by the simulation tool based on the input of net calorific value (NCV) of the fuel used in the verification test in accordance with Table 4a.

Additionally the data as set out in Table 4a shall be reported. This data shall be entered directly into the graphical user interface of the simulation tool when evaluating the verification test procedure.

Table 4a

Data reporting format for further information for the simulation tool in the verification test

Quantity	Unit	Comment
NCV measured	[MJ/kg]	Net calorific value (NCV) of the fuel used in the verification test determined in accordance with point 3.2 of Annex V. This input shall be provided for all fuel types, i.e. also for Diesel CI engines (1). In the case of dual-fuel engines, values for both fuels shall be provided.
Run-in distance	[km]	In accordance with point 6.1.2. Based on this input the simulation tool corrects the measured fuel consumption in accordance with Appendix 1.
Diameter fan	[mm]	Diameter of the engine cooling fan. This input is not relevant for electrically driven engine cooling fans.
Torque meter drift left wheel	[Nm]	Average torque meter readings in accordance with point 6.1.5.6.
Torque meter drift right wheel	[Nm]	

(1) In the VTP test, the vehicle may be operated with market Diesel fuel. Contrary to the situation for reference Diesel fuel (B7), the variation of the NCV for market fuel is assessed to be greater than the measuring accuracy when determining the NCV.

▼M3

7. Test evaluation

7.1. Input to the simulation tool

(1) The following inputs to the simulation tool shall be made available: Input data and input information;

(2) Manufacturer's records file;

(3) Customer information file;

(4) Processed measurement data in accordance with Table 4;

(5) Further information in accordance with Table 4a.

7.2. Evaluation steps as performed by the simulation tool

7.2.1. Verification of the data handling process

The simulation tool shall re-simulate the CO_2 emissions and fuel consumption based on the input information and input data defined in 7.1. and verify the corresponding results in the manufacturer's records file and the customer information file as provided by the manufacturer.

In the case of any deviations, the remedial measures referred to in Article 23 shall apply.

7.2.2. Determination of the C_{VTP} ratio

The test evaluation shall compare CO_2 emissions during the measurement with simulated CO_2 emissions. For this comparison the ratio of measured and simulated brake specific CO_2 emissions for the total verification test relevant trip (C_{VTP}) shall be calculated by the simulation tool in accordance with the following equation:

$$C_{VTP} = \frac{\sum_{i=1}^{n} BSFC_{m-c,i} \times CO2_i}{\sum_{i=1}^{n} BSFC_{sim,i} \times CO2_i}$$

Where:

C_{VTP} = ratio of CO_2 emissions measured and simulated in the verification testing procedure (‘C_{VTP} ratio’)

n = number of fuels (2 for dual-fuel engines, else 1)

CO_{2i} = generic CO_2 emission factor (grams CO_2 per gram fuel) for the specific fuel type as implemented in the simulation tool.

$BSFC_{m-c}$ = brake specific fuel consumption measured and corrected for a run-in phase as calculated in accordance with point 2 of part A in Appendix 1 [g/kWh]

$BSFC_{sim}$ = brake specific fuel consumption determined by the simulation tool in accordance with point 3 of part A in Appendix 1 [g/kWh]

7.3. Pass/Fail check

The vehicle shall pass the verification test if the C_{VTP} ratio determined in accordance with 7.2.2. is equal or smaller than the tolerance set out in Table 5.

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For a comparison with the declared CO_2 emissions of the vehicle in accordance with Article 9, the verified CO_2 emissions of the vehicle are determined as follows:

$$CO2_{verified} = C_{VTP} \times CO2_{declared}$$

where:

$CO_{2verified}$ = verified CO_2 emissions of the vehicle in [g/t-km]

$CO_{2declared}$ = declared CO_2 emissions of the vehicle in [g/t-km]

If a first vehicle fails the tolerances for C_{VTP}, two more tests may be performed on the same vehicle or two more similar vehicles may be tested on request of the vehicle manufacturer. For the evaluation of the pass criterion set out in Table 5, the averages of the individual C_{VTP} ratios from the up to three tests shall be used. If the pass criterion is not reached, the vehicle fails the verification testing procedure.

Table 5

Pass fail criterion for the verification test

Pass criterion for the verification testing procedure	C_{VTP} ratio ≤ 1,075

Where C_{VTP} is lower than 0,925, the results need to be reported to the Commission for further analysis to determine the cause.

8 Reporting procedures

The test report shall be established by the vehicle manufacturer for each vehicle tested and shall include at least the following results of the verification test:

8.1. General

8.1.1. Name and address of the vehicle manufacturer

8.1.2. Address(es) of assembly plant(s)

8.1.3. The name, address, telephone and fax numbers and e-mail address of the vehicle manufacturer's representative

8.1.4. Type and commercial description

8.1.5. Selection criteria for vehicle and CO_2 relevant components (text)

8.1.6. Vehicle owner

8.1.7. Odometer reading at test start of the fuel consumption measurement (km)

8.2. Vehicle information

8.2.1. Vehicle model / Commercial Name

8.2.2. Vehicle identification number (VIN)

8.2.2.1. Where the test has been performed following a situation in which the first vehicle test ends in failing the tolerances referred to in point 7.3, the vehicle identification number (VIN) of the vehicle tested first

8.2.3. Vehicle category (N_2, N_3)

8.2.4. Axle configuration

8.2.5. Technically permissible maximum laden mass (t)

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8.2.6. Vehicle group

8.2.7. Corrected actual mass of the vehicle (kg)

8.2.8. Cryptographic hash of the manufacturer's records file

8.2.9. Vehicle combination's gross combined weight in the verification test (kg)

8.2.10. Mass in running order

8.3. Main engine specifications

8.3.1. Engine model

8.3.2. Engine certification number

8.3.3. Engine rated power (kW)

8.3.4. Engine capacity (l)

8.3.5. Engine reference fuel type (diesel/LPG/CNG…)

8.3.6. Hash of the fuel map file/document

8.4. Main transmission specifications

8.4.1. Transmission model

8.4.2. Transmission certification number

8.4.3. Main option used for generation of loss maps (Option1/Option2/Option3/Standard values)

8.4.4. Transmission type

8.4.5. Number of gears

8.4.6. Transmission ratio final gear

8.4.7. Retarder type

8.4.8. Power take off (yes/no)

8.4.9. Hash of the efficiency map file/document

8.5. Main retarder specifications

8.5.1. Retarder model

8.5.2. Retarder certification number

8.5.3. Certification option used for generation of a loss map (standard values/measurement)

8.5.4. Hash of the retarder efficiency map file/document

8.6. Torque converter specification

8.6.1. Torque converter model

8.6.2. Torque converter certification number

8.6.3. Certification option used for generation of a loss map (standard values/measurement)

8.6.4. Hash of the efficiency map file/document

8.7. Angle drive specifications

8.7.1. Angle drive model

8.7.2. Axle certification number

8.7.3. Certification option used for generation of a loss map (standard values/measurement)

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8.7.4. Angle drive ratio

8.7.5. Hash of the efficiency map file/document

8.8. Axle specifications

8.8.1. Axle model

8.8.2. Axle certification number

8.8.3. Certification option used for generation of a loss map (standard values/measurement)

8.8.4. Axle type (e.g. standard single driven axle)

8.8.5. Axle ratio

8.8.6. Hash of the efficiency map file/document

8.9. Aerodynamics

8.9.1. Model

8.9.2. Certification option used for generation of CdxA (standard values /measurement)

8.9.3. CdxA Certification number (if applicable)

8.9.4. CdxA value

8.9.5. Hash of the efficiency map file/document

8.10. Main tyre specifications

8.10.1. Tyre certification number on all axles

8.10.2. Specific rolling resistance coefficient of all tyres on all axles

8.11. Main auxiliary specifications

8.11.1. Engine cooling fan technology

8.11.1.1 Engine cooling fan diameter

8.11.2. Steering pump technology

8.11.3. Electric system technology

8.11.4. Pneumatic system technology

8.12. Test conditions

8.12.1. Actual mass of the vehicle for VTP (kg)

8.12.2. Actual mass of the vehicle for VTP with payload (kg)

8.12.3. Warm up time (minutes)

8.12.4. Average velocity at warm up (km/h)

8.12.5. Fuel consumption measurement duration (minutes)

8.12.6. Distance based share urban driving (%)

8.12.7. Distance based share rural driving (%)

8.12.8. Distance based share motorway driving (%)

8.12.9. Time share of idling at stand still (%)

8.12.10. Average ambient temperature (°C)

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8.12.11. Road condition (dry, wet, snow, ice, others please specify)

8.12.12. Maximum sea level of the route (m)

8.12.13. Maximum duration of continuous idling at stand still (minutes)

8.13. Results of the verification test

8.13.1. Average fan power calculated for the verification test by the simulation tool (kW)

8.13.2. Positive wheel work over the verification test calculated by the simulation tool (kWh)

8.13.3. Positive wheel work over the verification test measured (kWh)

8.13.4. NCV of the fuel(s) used in the verification test (MJ/kg)

8.13.5. Fuel consumption value(s) in the verification test measured (g/kWh)

8.13.5.1 CO_2 emission value(s) in the verification test measured (g/kWh)

8.13.6. Fuel consumption value(s) in the verification test measured, corrected (g/kWh)

8.13.6.1 CO_2 emission value(s) in the verification test measured, corrected (g/kWh)

8.13.7. Fuel consumption value(s) in the verification test simulated (g/kWh)

8.13.7.1 CO_2 emission value(s) in the verification test simulated (g/kWh)

8.13.8. Fuel consumption in the verification test simulated (g/kWh)

8.13.8.1 CO_2 emission in the verification test simulated (g/kWh)

8.13.9. Mission profile (long haul / long haul (EMS) / regional / regional (EMS) / urban / municipal / construction)

8.13.10. Verified CO_2 emissions of the vehicle (g/tkm)

8.13.11. Declared CO_2 emissions of the vehicle (g/tkm)

8.13.12. Ratio of fuel consumption measured and simulated in the verification testing procedure (C_{VPT}) in (-)

8.13.13. Passed the verification test (yes/no)

8.13.14. Pollutant emissions in the verification test

8.13.14.1. CO (mg/kWh)

8.13.14.2. THC (**) (mg/kWh)

8.13.14.3. NMHC (***) (mg/kWh)

8.13.14.4. CH_4 (***) (mg/kWh)

8.13.14.5. NO_x (mg/kWh)

8.13.14.6. PM number (#/kWh)

8.13.14.7. Positive engine work (kWh)

▼**M3**

8.14. Software and user information

8.14.1. Simulation tool version (X.X.X)

8.14.2. Date and time of the simulation

8.15. Input to the simulation tool as set out in point 7.1.

8.16. Simulation output data

8.16.1. The aggregated simulation results

The comma separated values file of the same name as the job file and with an extension '.vsum' comprising the aggregated results of the simulated verification test that is generated by the simulation tool in its graphical user interface (GUI) version ('sum exec data file').

8.16.2. The time resolved simulation results

The comma separated values file with the name comprising the VIN and the measurement data file name and with an extension '.vmod' comprising the time resolved results of the simulated verification test that is generated by the simulation tool in its graphical user interface (GUI) version ('mod data file').

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Appendix 1

Main evaluation steps and equations as performed by the simulation tool in a verification testing procedure simulation

This Appendix describes the main evaluation steps and underlying basic equations that are applied by the simulation tool in a verification testing procedure simulation.

PART A: Determination of the C_{VTP} factor

For the determination of the C_{VTP} factor as described in point 7.2.2, the calculation procedures as set out below are applied:

1. Calculation of wheel power

The torque data as read from the processed measurement data in accordance with Table 4 is corrected for the torque meter drift as follows:

$$T_{corr-i}(t) = T_i(t) - T_{drift-i} \cdot \frac{t - t_{start}}{t_{end} - t_{start}}$$

where:

i	=	index standing for left and right wheel of the driven axle
T_{corr}	=	drift corrected torque signal [Nm]
T	=	torque signal before drift correction [Nm]
T_{drift}	=	torque meter drift as recorded during drift check at the end of the verification test [Nm]
t	=	time node [s]
t_{start}	=	first time stamp in the processed measurement data in accordance with Table 4 [s]
t_{end}	=	last time stamp in the processed measurement data in accordance with Table 4 [s]

The wheel power is calculated from the corrected wheel torque and rotational wheel speed as follows:

$$P_{wheel-i(t)} = \frac{2 \cdot \pi \cdot n_{wheel-i(t)} \cdot T_{corr-i(t)}}{60000}$$

where:

i	=	index standing for left and right wheel of the driven axle
t	=	time node [s]
P_{wheel}	=	wheel power [kW]
n_{wheel}	=	rotational wheel speed [rpm]
T_{corr}	=	drift corrected torque signal [Nm]

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The total wheel power is then calculated as the sum of the wheel power from left and right wheel:

$$P_{wheel(t)} = \sum_{i=1}^{2} P_{wheel-i(t)}$$

2. Determination of the measured brake specific fuel consumption ($FC_{m\text{-}c}$)

The result for 'brake specific fuel consumption measured and corrected for a run-in phase' ($BSFC_{m\text{-}c}$) as applied for in 7.2.2 is calculated by the simulation tool as described below.

In a first step the raw value for measured brake specific fuel consumption for the verification test $BSFC_m$ is calculated as follows:

$$BSFC_m = \frac{\sum_{tstart}^{tend} FC_{m(t)} \cdot \Delta t}{W_{wheel,pos,m}}$$

where:

$BSFC_m$ = raw value for measured brake specific fuel consumption in the verification test [g/kWh]

$FC_{m\ (t)}$ = instantaneous fuel mass flow measured during the verification test [g/s]

Δt = time increment duration = 0,5 [s]

$W_{wheel,pos,m}$ = positive wheel work measured in the verification test [kWh]

$$W_{wheel,pos,m} = \sum_{t_{start}}^{t_{end}} \frac{\max\ (P_{wheel(t)}, 0) \cdot \Delta t}{3600}$$

In a second step $BSFC_m$ is corrected for the net calorific value (NCV) of the fuel used in the verification test resulting in $BSFC_{m,corr}$:

$$BSFC_{m,corr} = BSFC_m \cdot \frac{NCV meas}{NCV std}$$

where:

$BSFC_{m,corr}$ = value for measured brake specific fuel consumption in the verification test corrected and for NCV influence [g/kWh]

NCV_{meas} = NCV of the fuel used in the verification test determined in accordance with point 3.2 of Annex V [MJ/kg]

NCV_{std} = standard NCV in accordance with Table 5 in point 5.4.3.1 of Annex V [MJ/kg]

This correction is applied for all fuel types, i.e. also for Diesel CI engines (see footnote 2 in Table 4a).

▼**M3**

In a third step the correction for a run-in phase is applied:

$$BSFC_{m-c} = BSFC_{m,corr} \cdot \min(1, \left(ef + mileage \cdot \frac{1 - ef}{15000}\right)) \text{ [g/kWh]}$$

where:

$BSFC_{m-c}$ = brake specific fuel consumption measured and corrected for a run-in phase

ef = evolution coefficient of 0,98

mileage = run-in distance [km]

For dual-fuel vehicles all three evaluation steps are performed separately for both fuels.

3. Determination of the brake specific fuel consumption simulated by the simulation tool ($BSFC_{sim}$)

In the verification test mode of the simulation tool the measured wheel power is applied as input to the backward simulation algorithm. The gears engaged during the verification test are determined by calculating the engine speeds per gear at the measured vehicle speed and selecting the gear that provides the engine speed closest to the measured engine speed. For APT transmissions during phases with active torque converter, the actual gear signal from the measurement is used.

The loss models for axle gear, angle drive, retarders, transmissions and PTOs are applied in a similar way as in the declaration mode of the simulation tool.

For power demand of auxiliary units concerning steering pump, pneumatic system, electric system and HVAC system the generic values as implemented per technology in the simulation tool are applied. For calculation of the power demand of the engine cooling fan the following formulas are applied:

Case a) non-electrically driven engine cooling fans:

$$P_{fan(t)} = C1 \cdot \left(\left(\frac{n_{fan(t)}}{C2}\right)^3 \cdot \left(\frac{D_{fan}}{C3}\right)^5\right)$$

where:

P_{fan} = power demand engine cooling fan [kW]

t = time node [s]

n_{fan} = measured rotational speed of the fan [rpm]

D_{fan} = diameter of the fan [mm]

C1 = 7,32 kW

C2 = 1 200 rpm

C3 = 810 mm

Case (b) electrically driven engine cooling fans:

$$P_{fan(t)} = P_{el(t)} \;.\; 1{,}05$$

P_{fan} = power demand engine cooling fan [kW]

t = time node [s]

P_{el} = electrical power at the terminals of the engine cooling fan(s) as measured in accordance with point 5.6.1.

▼**M3**

In the case of vehicles with engine stop-start events during the verification test, similar corrections for auxiliary power demand and energy to re-start the engine as applied in the declaration mode of the simulation tool are applied.

The simulation of the engines instantaneous fuel consumption $FC_{sim(t)}$ is performed for each 0,5 second time interval as follows:

— Interpolation from the engine fuel map using measured engine speed and resulting engine torque from the backward calculation including engines rotational inertia calculated from measured engine speed

— The engine torque demand as determined above is limited to the certified engine full-load capabilities. For those time intervals the wheel power in the backward simulation is reduced accordingly. In the calculation of $BSFC_{sim}$ as set out below this simulated wheel power trace ($P_{wheel,sim(t)}$) is taken into consideration.

— A WHTC correction factor is applied corresponding to the allocation of urban, rural and motorway based on the definitions as given in point 2(8) to 2(10) and the measured vehicle speed.

The brake specific fuel consumption calculated by the simulation tool $BSFC_{m-c}$ as applied in 7.2.2 for calculation of the C_{VTP} factor is calculated as follows:

$$BSFC_{sim} = \frac{\left(\sum_{tstart}^{tend} FC_{sim(t)} \cdot \Delta t\right) + FC_{ESS,corr}}{W_{wheel,pos,sim}}$$

where:

$BSFC_{sim}$	=	brake specific fuel consumption determined by the simulation tool for the verification test [g/kWh]
t	=	time node [s]
FC_{sim}	=	engines instantaneous fuel consumption [g/s]
Δt	=	time increment duration = 0,5 [s]
$FC_{ESS,corr}$	=	correction of fuel consumption regarding auxiliary power demand resulting from engine stop start (ESS) as applied in the declaration mode of the simulation tool [g]
$W_{wheel,pos,sim}$	=	positive wheel work determined by the simulation tool for the verification test [kWh]

$$W_{wheel,pos,sim} = \sum_{t_{start}}^{t_{end}} \frac{\max\left(P_{wheel,sim(t)}, 0\right)}{3600 \cdot fs}$$

fs	=	Simulation rate = 2 [Hz]
$P_{wheel,sim}$	=	Simulated wheel power for the verification test [kW]

In the case of dual-fuel engines, $BSFC_{sim}$ is determined for both fuels separately.

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PART B: Determination of the brake specific pollutant emissions

The engine power is calculated from the measured signals for engine speed and engine torque as follows:

$$P_{eng,m(t)} = \frac{2 \cdot \pi \cdot n_{eng(t)} \cdot T_{eng,m(t)}}{60000}$$

where:

$P_{eng,m}$ = measured engine power in the verification test[kW]

t = time node [s]

n_{eng} = measured rotational engine speed [rpm]

T_{eng} = measured engine torque [Nm]

The positive engine work measured in the verification test is calculated as follows:

$$W_{eng,pos,m} = \sum_{t_{start}}^{t_{end}} \frac{\max\left(P_{eng,m(t)}, 0\right)}{3600 \cdot fs}$$

$W_{eng,pos,m}$ = positive engine work measured in the verification test [kWh]

fs = sampling rate = 2 [Hz]

t_{start} = first time stamp in the processed measurement data in accordance with Table 4 [s]

t_{end} = last time stamp in the processed measurement data in accordance with Table 4 [s]

The brake specific pollutant emissions measured in the verification test BSEM are calculated as follows:

$$\text{BSEM} = \frac{\sum_{\text{tstart}}^{\text{tend}} EM(t)}{W_{eng,pos,m} \cdot fs}$$

where:

BSEM = brake specific pollutant emissions measured in the verification test [g/kWh]

EM = instantaneous pollutant emission mass flow measured during the verification test [g/s]

(*) Council Directive 96/53/EC of 25 July 1996 laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic (OJ L 235, 17.9.96, p. 59).

(**) Only if this component needs to be measured in accordance with point 1 of Appendix 1 to Annex II to Regulation (EU) 582/2011.

(***) For positive ignition engines.

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ANNEX Xb

CERTIFICATION OF ELECTRIC POWERTRAIN COMPONENTS

1. Introduction

The component test procedures described in this Annex shall produce input data relating to electric machine systems, IEPC, IHPC Type 1, battery systems and capacitor systems for the simulation tool.

2. Definitions and abbreviations

For the purposes of this Annex, the following definitions shall apply:

(1) ‘battery control unit’ or ‘BCU’ means an electronic device that controls, manages, detects or calculates electric and thermal functions of the battery system and that provides communication between the battery system or battery pack or part of a battery pack and other vehicle controllers.

(2) ‘battery pack’ means a REESS (rechargeable electric energy storage system) that includes secondary cells or secondary cell assemblies, which are normally connected with cell electronics, power supply circuits and overcurrent shut-off device, including electrical interconnections and interfaces for external systems (examples of external systems are systems intended for thermal conditioning, high voltage and low voltage auxiliary and communication).

(3) ‘battery system’ means a REESS that consists of secondary cell assemblies or battery pack(s) as well as electrical circuits, electronics, interfaces for external systems (e.g. thermal conditioning system), BCUs and contactors.

(4) ‘representative battery subsystem’ means a subsystem of a battery system that consists of either secondary cell assemblies or battery pack(s) in serial and/or parallel configuration with electrical circuits, thermal conditioning system interfaces, control units and cell electronics.

(5) ‘cell’ means a basic functional unit of a battery, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators, that is a source of electric energy obtained by direct conversion of chemical energy.

(6) ‘cell electronics’ means an electronic device that collects and possibly monitors thermal or electric data of cells or cell assemblies or capacitors or capacitor assemblies and contains electronics for balancing between cells or capacitors, if necessary.

(7) ‘secondary cell’ means a cell which is designed to be electrically recharged by way of a reversible chemical reaction.

(8) ‘capacitor’ means a device for storage of electrical energy achieved by the effects of electrostatic double-layer capacitance and electrochemical pseudo capacitance in an electrochemical cell.

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(9) ‘capacitor cell’ means a basic functional unit of a capacitor, consisting of an assembly of electrodes, electrolyte, container, terminals and usually separators.

(10) ‘capacitor control unit’ or ‘CCU’ means an electronic device that controls, manages, detects or calculates electric and thermal functions of the capacitor system and that provides communication between the capacitor system or capacitor pack or part of a capacitor pack and other vehicle controllers.

(11) ‘capacitor pack’ means a REESS that includes capacitor cells or capacitor assemblies normally connected with capacitor cell electronics, power supply circuits and overcurrent shut-off device, including electrical interconnections, interfaces for external systems and CCU. Examples of external systems are thermal conditioning, high voltage and low voltage auxiliary and communication.

(12) ‘capacitor system’ means a REESS that includes capacitor cells or capacitor assemblies or capacitor pack(s) as well as electrical circuits, electronics, interfaces for external systems (e.g. thermal conditioning system), CCU and contactors.

(13) ‘representative capacitor subsystem’ means a subsystem of a capacitor system that consists of either capacitor assemblies or capacitor pack(s) in serial and/or parallel configuration with electrical circuits, thermal conditioning system interfaces, control units and capacitor cell electronics.

(14) ‘nC’ means the current rate equal to n times the one hour discharge capacity expressed in ampere (i.e. current that takes 1/n hours to fully charge or discharge the tested device based on the rated capacity).

(15) ‘continuously variable transmission’ or ‘CVT’ means an automatic transmission that can change seamlessly through a continuous range of gear ratios.

(16) ‘differential’ means a device that splits a torque into two branches, e.g., for left- and right-hand side wheels, while allowing these branches to rotate at unequal speeds. The torque-splitting function can be biased or deactivated by a differential brake- or differential lock device (if applicable).

(17) ‘differential gear ratio’ means the ratio of differential input speed (towards the primary propulsion energy converter) over differential output speed (towards driven wheels) with both differential output shafts running at the same speed.

(18) ‘drivetrain’ means the connected elements of the powertrain for transmission of the mechanical energy between the propulsion energy converter(s) and the wheels.

(19) ‘electric machine’ (EM) means an energy converter transforming between electrical and mechanical energy.

(20) ‘electric machine system’ means a combination of electric powertrain components as installed in the vehicle comprising of an electric machine, inverter and electronic control unit(s), including connections and interfaces for external systems

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(21) ‘electric machine type’ is either (a) an asynchronous machine (ASM), (b) an excited synchronous machine (ESM), (c) a permanent magnet synchronous machine (PSM), or (d) a reluctance machine (RM).

(22) ‘ASM’ means an asynchronous electric machine type in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding.

(23) ‘ESM’ means an excited synchronous electric machine type which contains multiphase AC electromagnets on the stator that create a magnetic field which rotates in time with the oscillations of the line current. It requires direct current supplied to the rotor for excitation.

(24) ‘PSM’ means a permanent magnet sychronous electric machine type which contains multiphase AC electromagnets on the stator that create a magnetic field which rotates in time with the oscillations of the line current. Permanent magnets embedded in the steel rotor create a constant magnetic field.

(25) ‘RM’ means a reluctance electric machine type which contains multiphase AC electromagnets on the stator that create a magnetic field which rotates in time with the oscillations of the line current. It induces non-permanent magnetic poles on the ferromagnetic rotor which does not have any windings. It generates torque through magnetic reluctance.

(26) ‘housing’ means an integrated and structural part of the component, enclosing the internal units and providing protection against direct contact from any direction of access.

(27) ‘energy converter’ means a system where the form of energy output is different from the form of energy input.

(28) ‘propulsion energy converter’ means an energy converter of the powertrain which is not a peripheral device whose output energy is used directly or indirectly for the purpose of vehicle propulsion.

(29) ‘category of propulsion energy converter’ means (i) an internal combustion engine, (ii) an electric machine, or (iii) a fuel cell.

(30) ‘energy storage system’ means a system which stores energy and releases it in the same form as the input energy.

(31) ‘propulsion energy storage system’ means an energy storage system of the powertrain which is not a peripheral device and whose output energy is used directly or indirectly for the purpose of vehicle propulsion.

(32) ‘category of propulsion energy storage system’ means (i) a fuel storage system, (ii) a rechargeable electric energy storage system (REESS), or (iii) a rechargeable mechanical energy storage system.

(33) ‘form of energy’ means (i) electrical energy, (ii) mechanical energy, or (iii) chemical energy (including fuels).

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(34) ‘fuel storage system’ means a propulsion energy storage system that stores chemical energy as liquid or gaseous fuel.

(35) ‘gearbox’ means a device changing torque and speed with defined fixed ratios for each gear which may include the functionality of shiftable gears as well

(36) ‘gear number’ means an identifier for the different shiftable gears for forward direction in a transmission with specific gear ratios; the shiftable gear with the highest gear ratio gets assigned the number 1; the identifying number is increased by the increment of 1 for each gear in descending order of gear ratios.

(37) ‘gear ratio’ means the forward gear ratio of the speed of the input shaft (towards the primary propulsion energy converter) to the speed of the output shaft (towards driven wheels) without slip.

(38) ‘high-energy battery system’ or ‘HEBS’ means a battery system or representative battery subsystem, for which the numerical ratio between maximum discharge current in A, declared by the component manufacturer at a SOC of 50 % in accordance with point 5.4.2.3.2, and the nominal electric charge output in Ah at a 1C discharge rate at RT is lower than 10.

(39) ‘high-power battery system’ or ‘HPBS’ means a battery system or representative battery subsystem, for which the numerical ratio between maximum discharge current in A, declared by the component manufacturer at a SOC of 50 % in accordance with point 5.4.2.3.2, and the nominal electric charge output in Ah at a 1C discharge rate at RT is equal to or higher than 10.

(40) ‘integrated electric powertrain component’ or ‘IEPC’ means a combined system of an electric machine system together with the functionality of either a single- or multi-speed gearbox or a differential or both, characterised by at least one of the following features:

— shared housing of at least two components

— shared lubrication circuit of at least two components

— shared cooling circuit of at least two components

— shared electric connection of at least two components

Additionally, an IEPC shall comply with the following criteria:

— It shall have only output shaft(s) towards the driven wheels of the vehicle and shall have no input shaft(s) for feeding propulsion torque into the system.

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— In the case of more than one electric machine system being part of the IEPC, all electric machines shall be connected to a single DC power source for all test runs performed in accordance with this Annex.

— In the case of the functionality of a multi-speed gearbox being included, there shall be only discrete gear steps.

(41) 'IEPC design type wheel motor' means an IEPC with either one output shaft or two output shafts connected directly to the wheel hub(s) and where two configurations shall be distinguished for the purpose of this Annex:

— Configuration 'L': In the case of one output shaft, the same component is installed twice in symmetrical application (i.e. one on the left and one on the right side of the vehicle at the same wheel position in longitudinal direction).

— Configuration 'T': In the case of two output shafts, only a single component is installed with one output shaft connected to the left and the other output shaft connected to the right side of the vehicle at the same wheel position in longitudinal direction.

(42) 'integrated hybrid electric vehicle powertrain component type 1' or 'IHPC Type 1' means a combined system of multiple electric machine systems together with the functionality of a multi-speed gearbox characterised by a shared housing of all components and at least one of the following features:

— shared lubrication circuit of at least two components

— shared cooling circuit of at least two components

— shared electric connection of at least two components

Additionally, an IHPC Type 1 shall comply with the following criteria:

— It shall have only one input shaft for feeding propulsion torque into the system and only one output shaft towards the driven wheels of the vehicle.

— Only discrete gear steps shall be used for all test runs performed in accordance with this Annex.

— It shall enable operation of the powertrain as parallel hybrid (at least in one specific mode used for all test runs performed in accordance with this Annex).

— It shall be able to be tested in the transmission test in accordance with Annex VI with the electric power supply disconnected in accordance with subpoint (b) of point 4.4.1.2.

— All electric machines shall be connected to a single DC power source for all test runs performed in accordance with this Annex.

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— The gearbox part within the IHPC Type 1 shall not be operated as CVT for all test runs performed in accordance with this Annex.

— A hydrodynamic torque converter shall not be part of the IHPC Type 1.

(43) 'internal combustion engine' or 'ICE' means an energy converter with intermittent or continuous oxidation of combustible fuel transforming between chemical and mechanical energy.

(44) 'inverter' means an electric energy converter that changes direct electric current to single-phase or polyphase alternating electric currents

(45) 'peripheral device' means any energy consuming, converting, storing or supplying devices, where the energy is not directly or indirectly used for the purpose of vehicle propulsion but which are essential to the operation of the powertrain and are therefore considered to be part of the powertrain.

(46) 'powertrain' means the total combination in a vehicle of propulsion energy storage system(s), propulsion energy converter(s) and the drivetrain(s) providing the mechanical energy at the wheels for the purpose of vehicle propulsion, plus peripheral devices.

(47) 'rated capacity' means the total number of ampere-hours that can be withdrawn from a fully charged battery determined in accordance with point 5.4.1.3

(48) 'rated speed' means the highest rotational speed of the electric machine system where the overall maximum torque occurs

(49) 'room temperature' or 'RT' means that the ambient air inside the test cell shall have a temperature of (25 ± 10) °C

(50) 'state of charge' or 'SOC' means the available electrical charge stored in a battery system expressed as a percentage of its rated capacity in accordance with 5.4.1.3 (where 0 % represents empty and 100 % represents full)

(51) 'unit under test' or 'UUT' means the electric machine system, IEPC or IHPC Type 1 to be actually tested

(52) 'battery UUT' means the battery system or representative battery subsystem to be actually tested

(53) 'capacitor UUT' means the capacitor system or representative capacitor subsystem to be actually tested.

For the purposes of this Annex, the following abbreviations shall apply:

AC alternating current

DC direct current

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DCIR direct current internal resistance

EMS electric machine system

OCV open circuit voltage

SC standard cycle

3. General requirements

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

3.1 Measurement equipment specifications

The measurement equipment shall meet the following accuracy requirements:

Table 1

Requirements of measurement systems

Measurement system	Accuracy (1)
Rotational speed	0,5 % of the analyser reading or 0,1 % of max. calibration (2) of rotational speed whichever is larger
Torque	0,6 % of the analyser reading or 0,3 % of max. calibration (2) or 0,5 Nm of torque whichever is larger
Current	0,5 % of the analyser reading or 0,25 % of max. calibration (2) or 0,5 A of current whichever is larger
Voltage	0,5 % of the analyser reading or 0,25 % of max. calibration (2) of voltage whichever is larger
Temperature	1,5 K

(1) 'Accuracy' means the absolute value of deviation of the analyser reading from a reference value which is traceable to a national or international standard.
(2) The 'maximum calibration' value shall be the maximum predicted value for the respective measurement system expected during a specific test run performed in accordance with this Annex multiplied by a factor of 1.1.

Multi-point calibration shall be allowed which means that a measurement system is allowed to be calibrated up to a nominal value which is less than the capacity of the measurement system.

3.2 Data recording

All measurement data, except temperature, shall be measured with and recorded at a frequency of not less than 100 Hz. For temperature a measurement frequency of not less than 10 Hz is sufficient.

Signal filtering may be applied in agreement with the approval authority. Any aliasing effect shall be avoided.

4. Testing of electric machine systems, IEPCs and IHPCs Type 1

4.1 Test conditions

The UUT shall be installed and the measurands current, voltage, electric inverter power, rotational speed and torque shall be defined in accordance with Figure 1 and point 4.1.1.

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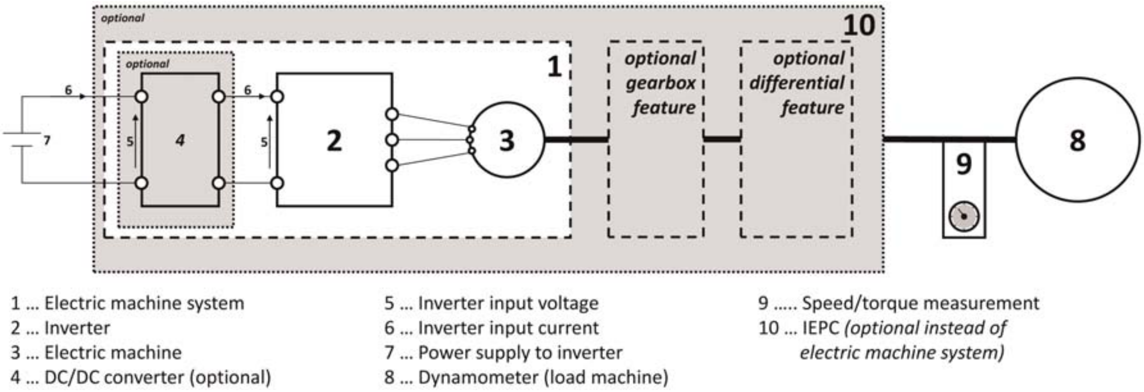
Figure 1

Provisions for measurement of electric machine system or IEPC



4.1.1 Equations for power figures

Power figures shall be calculated in accordance with the following equations:

4.1.1.1 Inverter power

The electric power to or from the inverter (or DC/DC converter if applicable) shall be calculated in accordance with the following equation:

$$P_{INV\_in} = V_{INV\_in} \times I_{INV\_in}$$

where:

P_{INV_in} is the electric inverter power to or from the inverter (or DC/DC converter if applicable) on the DC side of the inverter (or on the side of the DC powersource of the DC/DC converter) [W]

V_{INV_in} is the voltage at the inverter (or DC/DC converter if applicable) input on the DC side of the inverter (or on the side of the DC powersource of the DC/DC converter) [V]

I_{INV_in} is the current at the inverter (or DC/DC converter if applicable) input on the DC side of the inverter (or on the side of the DC powersource of the DC/DC converter) [A]

In the case of multiple connections of inverter(s) (or DC/DC converter(s) if applicable) to the electric DC powersource as defined in accordance with point 4.1.3, the total sum of all different electric inverter powers shall be measured.

4.1.1.2 Mechanical output power

The mechanical output power of the UUT shall be calculated in accordance with the following equation:

$$P_{UUT\_out} = \frac{2 \times \pi}{60} \times T_{UUT} \times n$$

where

P_{UUT_out} is the mechanical output power of the UUT [W]

T_{UUT} is the torque of the UUT [Nm]

n is the rotational speed of the UUT [min^{-1}]

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For an electric machine system the torque and speed shall be measured at the rotational shaft. For an IEPC the torque and speed shall be measured at the output side of the gearbox or, if a differential is also included, at the output side(s) of the differential.

For an IEPC with integrated differential, the output torque measuring device(s) can either be installed on both output sides, or only one of the output sides. For test setups with only one dynamometer on the output side, the free rotating end of the IEPC with integrated differential shall be rotatably locked to the other end on the output side (e.g., by an activated differential lock or by means of any other mechanical differential lock implemented only for the measurement).

In the case of an IEPC design type wheel motor, either one single component or two such components may be measured. Where two such components are measured, the following provisions shall apply, depending on the configuration:

— For configuration 'L' torque and speed shall be measured at the output side of the gearbox. In this case the input parameter 'NrOfDesignTypeWheelMotorMeasured' shall be set to 1.

— For configuration 'T', the output torque measuring device(s) can either be installed on both output shafts or only on one of the output shafts.

(a) Where the output torque measuring devices are installed on both output shafts, the following provisions shall apply:

— The torque values of both output shafts shall be summed up virtually in the test bench data processing or the data post-processing.

— The speed values of both output shafts shall be averaged virtually in the test bench data processing or post-processing.

— In this case the input parameter 'NrOfDesignTypeWheelMotorMeasured' shall be set to 2.

(b) Where an output torque measuring device is installed only on one of the output shafts, the following provisions shall apply:

— Torque and speed are measured at the output side of the gearbox.

— In this case the input parameter 'NrOfDesignTypeWheelMotorMeasured' shall be set to 1.

4.1.2 Run-in

On request of the applicant a run-in procedure may be applied to the UUT. The following provisions shall apply for a run-in procedure:

— The total run-time for the optional run-in and the measurement of an UUT (except wheel-ends) shall not exceed 120 hours.

— Only factory fill oil shall be used for the run-in procedure. The oil used for the run-in may also be used for the testing performed in accordance with point 4.2.

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— The speed and torque profile for the run-in procedure shall be specified by the component manufacturer.

— The run-in procedure shall be documented by the component manufacturer with regard to run-time, speed, torque and oil temperature and reported to the approval authority.

— The requirements for the oil temperature (point 4.1.8.1), measurement accuracy (point 3.1) and test setup (points 4.1.3 to 4.1.7) shall not apply for the run-in procedure.

4.1.3 Power supply to inverter

The power supply to the inverter (or DC/DC converter if applicable) shall be a direct-current constant-voltage power supply, which is capable of supplying/absorbing adequate electric power to/from the inverter (or DC/DC converter if applicable) at the maximum (mechanical or electrical) power of the UUT for the duration of the test runs specified in this Annex.

The DC input voltage to the inverter (or DC/DC converter if applicable) shall be in a range of ±2 % of the requested target value of DC input voltage to the UUT during all periods where actual measurement data is recorded that is used as a basis for determining input data for the simulation tool.

Table 2 in paragraph 4.2 defines which test runs shall be performed at which voltage level(s). There are 2 different voltage levels defined for the measurements to be performed:

— $V_{min,Test}$ shall be the target value of the DC input voltage to the UUT corresponding to the minimum voltage for unlimited operating capability.

— $V_{max,Test}$ shall be the target value of the DC input voltage to the UUT corresponding to the maximum voltage for unlimited operating capability.

4.1.4 Setup and wiring

All wiring, shielding, brackets, etc. shall be in accordance with conditions specified by the manufacturer(s) of the different components of the UUT.

4.1.5 Cooling system

The temperature of all parts of the electric machine system shall be within the range allowed by the component manufacturer during the whole operating time of all test runs performed in accordance with this Annex. For IEPC and IHPC Type 1 this includes also all other components as gearboxes and axles being part of the IEPC or IHPC Type 1.

4.1.5.1 Cooling power during test runs

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4.1.5.1.1 Cooling power for measurement of torque limitations

For all test runs performed in accordance with point 4.2, except for the EPMC in accordance with paragraph 4.2.6, the component manufacturer has to declare the number of used cooling circuits with connection to an external heat exchanger. For each of these circuits with connection to an external heat exchanger the following parameters at the inlet of the respective cooling circuit of the UUT shall be declared:

— the maximum coolant mass flow or maximum inlet pressure as specified by the component manufacturer

— the admitted maximum coolant temperatures as specified by the component manufacturer

— maximum available cooling power on the testbench

These declared values shall be documented in the information document for the respective component.

The following actual values shall remain below the declared maximum values and be recorded for each cooling circuit with connection to an external heat exchanger, together with the test data for all different test runs performed in accordance with point 4.2 except for the EPMC in accordance with point 4.2.6:

— coolant volume flow or mass flow

— coolant temperature at the inlet of the cooling circuit of the UUT

— coolant temperature at the inlet and outlet of the test bed heat exchanger on the side of the UUT

For all test runs performed in accordance with point 4.2, the minimum temperature of the coolant at the inlet of the cooling circuit of the UUT, in the case of liquid cooling shall be 25 °C.

Where fluids other than the regular cooling fluids are used for testing in accordance with this Annex, they must not exceed the temperature limits as defined by the component manufacturer.

In the case of liquid cooling, the maximum available cooling power on the testbench shall be determined based on the coolant massflow, the temperature difference over the test bed heat exchanger on the side of the UUT and the specific heat capacity of the coolant.

No additional fan with the purpose of actively cooling the components of the UUT shall be allowed in the test setup.

4.1.6 Inverter

The inverter shall be operated in the same mode and settings as specified for the actual in-vehicle using conditions by the component manufacturer.

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4.1.7 Ambient conditions in test cell

All tests shall be performed at an ambient temperature in the testcell of 25 ± 10 °C. The ambient temperature shall be measured within a distance of 1 m to the UUT.

4.1.8 Lubricating oil for IEPCs or IHPC Type 1

Lubricating oil shall fulfill the provisions defined in points 4.1.8.1 to 4.1.8.4 below. These provisions shall not apply to EM systems.

4.1.8.1 Oil temperatures

The oil temperatures shall be measured at the centre of the oil sump or at any other suitable point in accordance with good engineering practice.

An auxiliary regulating system in accordance with paragraph 4.1.8.4 may be used, if necessary, to maintain the temperatures within the specified limits by the component manufacturer.

In the case of external oil conditioning which is added for testing purposes only, the oil temperature may be measured in the outlet line from the housing of the UUT to the conditioning system within 5 cm downstream of the outlet. In both cases the oil temperature shall not exceed the temperature limit as specified by the component manufacturer. Solid engineering rationale shall be provided to the type approval authority to explain that the external oil conditioning system is not used to improve the efficiency of the UUT. For oil circuits which are neither part of, nor connected to the cooling circuit of any components of the electric machine system, the temperature shall not exceed 70 °C.

4.1.8.2 Oil quality

Only recommended factory fill oils as specified by the component manufacturer of the UUT shall be used for the measurement.

4.1.8.3 Oil viscosity

If different oils are specified for the factory fill, the component manufacturer shall choose an oil for which the kinematic viscosity (KV) at the same temperature is within a range of ±10 % of the kinematic viscosity of the oil with the highest viscosity (within the specified tolerance band for KV100) for performing the measurements of the UUT related to certification.

4.1.8.4 Oil level and conditioning

The oil level or filling volume shall be within the maximum and minimum levels as defined in the component manufacturer's maintenance specifications.

An external oil conditioning and filtering system is permitted. The housing of the UUT may be modified for the inclusion of the oil conditioning system.

The oil conditioning system shall not be installed in a way which would enable changing oil levels of the UUT in order to raise efficiency or to generate propulsion torques in accordance with good engineering practice.

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4.1.9 Sign conventions

4.1.9.1 Torque and power

Measured values of torque and power shall have a positive sign for the UUT driving the dyno and a negative sign for the UUT braking the dyno (i.e. dyno driving the UUT).

4.1.9.2 Current

Measured values of current shall have a positive sign for the UUT drawing electric power from the power supply to the inverter (or DC/DC converter if applicable) and a negative sign for the UUT delivering electric power to the inverter (or DC/DC converter if applicable) and to the power supply.

4.2 Test runs to be performed

Table 2 defines all test runs to be performed for the purpose of certification of one specific electric machine system family or IEPC family defined in accordance with Appendix 13.

The electric power mapping cycle (EPMC) in accordance with point 4.2.6 and the drag curve in accordance with point 4.2.3 shall be omitted for all other members within a family except the parent of the family.

Where, upon request of the component manufacturer, Article 15(5) of this Regulation is applied, the EPMC in accordance with point 4.2.6 and the drag curve in accordance with point 4.2.3 shall be performed additionally for that specific EM or IEPC.

Table 2

Overview of test runs to be performed for electric machine systems or IEPCs

Test run	Reference to point	Required voltage level(s) to be performed (in accordance with 4.1.3)	Required to be run for parent	Required to be run for other members within a family
Maximum and minimum torque limits	4.2.2	$V_{min,Test}$ and $V_{max,Test}$	yes	yes
Drag curve	4.2.3	Either $V_{min,Test}$ or $V_{max,Test}$	yes	no
Maximum 30 minutes continuous torque	4.2.4	$V_{min,Test}$ and $V_{max,Test}$	yes	yes
Overload characteristics	4.2.5	$V_{min,Test}$ and $V_{max,Test}$	yes	yes
EPMC	4.2.6	$V_{min,Test}$ and $V_{max,Test}$	yes	no

4.2.1 General provisions

The measurement shall be performed with all temperatures of the UUT during the test kept within the component manufacturer defined limit values.

All tests need to be performed with de-rating functionality depending on temperature limits of the electric machine system fully active. Where additional parameters of other systems located outside of the electric machine system's boundaries do influence the de-rating behaviour in in-vehicle applications, these additional parameters shall not be taken into account for all test runs performed in accordance with this Annex.

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For an electric machine system all torque and speed values indicated shall refer to the rotational shaft of the electric machine unless stated otherwise.

For an IEPC all torque and speed values indicated shall refer to the output side of the gearbox or, if a differential is also included, to the output side of the differential unless stated otherwise.

4.2.2 Test of maximum and minimum torque limits

The test measures the maximum and minimum torque characteristics of the UUT in order to verify the declared limitations of the system.

For IEPC with multispeed gearbox the test shall be performed only for the gear with the gear ratio closest to 1. Where the gear ratios of two gears have the same distance to a gear ratio of 1, the test shall be performed only for the gear with the higher of the two gear ratios.

4.2.2.1 Declaration of values by the component manufacturer

The component manufacturer shall declare the values for the maximum and minimum torque of the UUT as a function of the rotational speed of the UUT between 0 rpm and the maximum operating speed of the UUT prior to the test. This declaration shall be separately made for each of the two voltage levels $V_{min,Test}$ and $V_{max,Test}$.

4.2.2.2 Verification of maximum torque limits

The UUT shall be conditioned (i.e. without operating the system) at an ambient temperature of 25 ± 10 °C for a minimum of two hours until the start of the test run. If this test is performed directly consecutive to any other test run performed in accordance with this Annex the conditioning for a minimum of two hours may be omitted or shortened as long as the UUT stays within the testcell with the ambient temperature in the testcell kept within 25 ± 10 °C.

Just before beginning the test, the UUT shall be run on the bench for three minutes delivering a power equal to 80 % of the maximum power at the speed recommended by the component manufacturer.

The output torque and rotational speed of the UUT shall be measured at at least 10 different rotational speeds to define correctly the maximum torque curve between lowest and the highest speed.

The lowest speed setpoint shall be specified by the component manufacturer at a speed equal or smaller than 2 % of the maximum operating speed of the UUT as declared by the component manufacturer in accordance with point 4.2.2.1. Where the test setup does not allow operating the system at such a low speed setpoint, the lowest speed setpoint shall be specified by the component manufacturer as the lowest speed which can be realised by the specific test setup.

The highest speed setpoint shall be defined by the maximum operating speed of the UUT as declared by the component manufacturer in accordance with point 4.2.2.1.

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The remaining 8 or more different rotational speed setpoints shall be located between the lowest and highest speed setpoint and shall be specified by the component manufacturer. The interval between two adjacent speed setpoints shall not be larger than 15 % of the maximum operating speed of the UUT as declared by the component manufacturer.

All operating points shall be held for an operating time of at least 3 seconds. Output torque and rotational speed of the UUT shall be recorded as average value of the last second of the measurement. The whole test shall be completed within 5 minutes.

4.2.2.3 Verification of minimum torque limits

The UUT shall be conditioned (i.e. without operating the system) at an ambient temperature of 25 ±10 °C for a minimum of two hours until the start of the test run. If this test is performed directly consecutive to any other test run performed in accordance with this Annex the conditioning for a minimum of two hours may be omitted or shortened as long as the UUT stays within the testcell with the ambient temperature in the testcell kept within 25 ±10 °C.

Just before beginning the test, the UUT shall be run on the bench for three minutes delivering a power equal to 80 % of the maximum power at the speed recommended by the component manufacturer.

The output torque and rotational speed of the UUT shall be measured at the same rotational speeds as selected in point 4.2.2.2.

All operating points shall be held for an operating time of at least 3 seconds. Output torque and rotational speed of the UUT shall be recorded as average value of the last second of the measurement. The whole test shall be completed within 5 minutes.

4.2.2.4 Interpretation of results

The maximum torque of the UUT as declared by the component manufacturer in accordance with point 4.2.2.1 shall be accepted as final values if they are not higher than + 2 % for overall maximum torque and than +4 % at the other measurement points with a tolerance of ± 2 % for rotational speeds from the values measured in accordance with point 4.2.2.2.

Where the values for maximum torque declared by the component manufacturer exceed the limits defined above, the actual measured values shall be used as final values.

Where the values for maximum torque of the UUT as declared by the component manufacturer in accordance with point 4.2.2.1 are lower than the values measured in accordance with point 4.2.2.2, the values declared by the component manufacturer shall be used as final values.

The minimum torque of the UUT as declared by the component manufacturer in accordance with point 4.2.2.1 shall be accepted as final values if they are not lower than -2 % for overall minimum torque and than – 4% at the other measurement points with a tolerance of ±2 % for rotational speeds from the values measured in accordance with point 4.2.2.3.

Where the values for minimum torque declared by the component manufacturer exceed the limits defined above, the actual measured values shall be used as final values.

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Where the values for minimum torque of the UUT as declared by the component manufacturer in accordance with point 4.2.2.1 are higher than the values measured in accordance with point 4.2.2.3, the values declared by the component manufacturer shall be used as final values.

4.2.3 Test of drag curve

The test measures the drag losses in the UUT, i.e. the mechanical and/or electrical power necessary to spin the system at a certain speed by external power sources.

The UUT shall be conditioned (i.e. without operating the system) at an ambient temperature of 25 ±10 °C for a minimum of two hours. If this test is performed directly consecutive to any other test run performed in accordance with this Annex the conditioning for a minimum of two hours may be omitted or shortened as long as the UUT stays within the testcell with the ambient temperature in the testcell kept within 25 ±10 °C.

Just before beginning of the actual test, the UUT may optionally be run on the bench for three minutes delivering a power equal to 80 % of the maximum power at the speed recommended by the component manufacturer.

The actual test shall be performed in accordance with one of the following options:

— Option A: The output shaft of the UUT shall be connected to a load machine (i.e. dynamometer) and the load machine (i.e. dynamometer) shall be driving the UUT at the target rotational speed. Either the electric power supply to the inverter (or DC/DC converter if applicable) or the AC phase cables between the electric machine and inverter may be set inactive or disconnected.

— Option B: The output shaft of the UUT shall not be connected to a load machine (i.e. dynamometer) and the UUT shall be operated at the target rotational speed by electric power supplied to the inverter (or DC/DC converter if applicable).

— Option C: The output shaft of the UUT shall be connected to a load machine (i.e. dynamometer) and the UUT shall be operated at the target rotational speed either by the load machine (i.e. dynamometer) or the electric power supplied to the inverter (or DC/DC converter if applicable) or a combination of both

The test shall be performed at least at the same rotational speeds as selected in point 4.2.2.2, more operating points at other rotational speeds may be added. All operating points shall be held for an operating time of at least 10 seconds, during which the actual rotational speed of the UUT shall be within ± 2 % of the setpoint for rotational speed.

The following values shall be recorded as average value over the last 5 seconds of the measurement, depending on the chosen testing option:

— For option B and C above: electric power to the inverter (or DC/DC converter if applicable)

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— For option A and C above: the torque of the load machine (i.e. dynamometer) applied to the output shaft(s) of the UUT

— For all options: the rotational speed of the UUT

Where the UUT is an IEPC with multispeed gearbox, the test shall be performed for the gear with the gear ratio closest to 1. Where the gear ratios of two gears have the same distance to a gear ratio of 1, the test shall be performed only for the gear with the higher of the two gear ratios.

Additionally, the test may be performed also for all other forward gears of the IEPC so that a dedicated dataset for each forward gear of the IEPC is determined.

4.2.4 Test of maximum 30 minutes continuous torque

The test measures the maximum 30 minutes continuous torque which can be achieved by the UUT on average over a duration of 1 800 seconds.

For IEPC with multispeed gearbox the test shall be performed only for the gear with the gear ratio closest to 1. Where the gear ratios of two gears have the same distance to a gear ratio of 1, the test shall be performed only for the gear with the higher of the two gear ratios.

4.2.4.1 Declaration of values by the component manufacturer

The component manufacturer shall declare the values for the maximum 30 minutes continuous torque of the UUT as well as the corresponding rotational speed prior to the test. The rotational speed shall be in a range, in which the mechanical power is greater than 90 % of the overall maximum power determined from the maximum torque limit data recorded in accordance with point 4.2.2 for the respective voltage level. This declaration shall be separately made for each of the two voltage levels $V_{min,Test}$ and $V_{max,Test}$.

4.2.4.2 Verification of maximum 30 minutes continuous torque

The UUT shall be conditioned (i.e. without operating the system) at an ambient temperature of 25 ±10 °C for a minimum of four hours. If this test is performed directly consecutive to any other test run performed in accordance with this Annex the conditioning for a minimum of four hours may be omitted or shortened as long as the UUT stays within the testcell with the ambient temperature in the testcell kept within 25 ±10 °C.

The UUT shall be run at the torque and speed setpoint which corresponds to the maximum 30 minutes continuous torque declared by the component manufacturer in accordance with point 4.2.4.1 for a total period of 1 800 seconds.

The output torque and rotational speed of the UUT as well as the electric power to or from the inverter (or DC/DC converter if applicable) shall be measured over this period of 1 800 seconds. The mechanical power value measured over time shall be in a range of ±5 % of the mechanical power value declared by the component manufacturer in accordance with paragraph 4.2.4.1, the rotational speed shall be within ±2 % of the value declared by the component manufacturer in accordance with point 4.2.4.1. The maximum 30 minutes continuous torque is the average of the output torque within the 1 800-second measurement period. The corresponding rotational speed is the average of the rotational speed within the 1 800-second measurement period.

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4.2.4.3 Interpretation of results

The values declared by the component manufacturer in accordance with point 4.2.4.1 shall be accepted as final values if they do not differ by more than +4 % for torque with a tolerance of ±2 % for rotational speed from the average values determined in accordance with point 4.2.4.2.

Where the values declared by the component manufacturer exceed the limits defined above, the requirements referred to in points 4.2.4.1 to 4.2.4.3 shall be repeated with different values for the maximum 30 minutes continuous torque and/or the corresponding rotational speed.

Where the value for torque declared by the component manufacturer in accordance with point 4.2.4.1 is lower than the average value for torque determined in accordance with point 4.2.4.2 with a tolerance of ±2 % for rotational speed, the values declared by the component manufacturer shall be used as final values.

Additionally, the average of the actual measured electric power to or from the inverter (or DC/DC converter if applicable) over the 1 800-second measurement period shall be calculated. Also the average 30 minutes continuous power shall be calculated from the final values of maximum 30 minutes continuous torque and the corresponding average rotational speed.

4.2.5 Test of overload characteristics

The test measures the duration of the capability of the UUT to provide the maximum output torque in order to derive the overload characteristics of the system.

For IEPC with multispeed gearbox the test shall be performed only for the gear with the gear ratio closest to 1. Where the gear ratios of two gears have the same distance to a gear ratio of 1, the test shall be performed only for the gear with the higher of the two gear ratios.

4.2.5.1 Declaration of values by the component manufacturer

The component manufacturer shall declare the value for the maximum output torque of the UUT at the specific rotational speed chosen for the test as well as the corresponding rotational speed prior to the test. The corresponding rotational speed shall be the same speed setpoint as used for the measurement performed in accordance with point 4.2.4.2 for the respective voltage level. The declared value for the maximum output torque of the UUT shall be equal or greater than the value of the maximum 30 minutes continuous torque determined in accordance with point 4.2.4.3 for the respective voltage level.

In addition the component manufacturer shall declare a duration t_{0_maxP} for which the maximum output torque of the UUT can be constantly achieved starting from the conditions as set out in point 4.2.5.2. This declaration shall be separately made for each of the two voltage levels $V_{min,Test}$ and $V_{max,Test}$.

4.2.5.2 Verification of maximum output torque

The UUT shall be conditioned (i.e. without operating the system) at an ambient temperature of 25 °C ± 10 °C for a minimum of two hours. If this test is performed directly consecutive to any other test run performed in accordance with this Annex the conditioning for a minimum of two hours may be omitted or shortened as long as the UUT stays within the testcell with the ambient temperature in the testcell kept within 25 ±10 °C.

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Just before beginning the test, the UUT shall be run on the bench for 30 minutes delivering 50 % of the maximum 30 minutes continuous torque at the respective speed setpoint as determined in accordance with point 4.2.4.3.

Then the UUT shall be run at the torque and speed setpoint which corresponds to the maximum output torque declared by the component manufacturer in accordance with point 4.2.5.1.

The output torque and rotational speed of the UUT as well as the DC input voltage to the inverter (or DC/DC converter if applicable) and the electric power to or from the inverter (or DC/DC converter if applicable) shall be measured over a period of t_{0_maxP} declared by the component manufacturer in accordance with point 4.2.5.1.

4.2.5.3 Interpretation of results

The recorded values for torque and speed over time measured in accordance with point 4.2.5.2 shall be accepted if they do not differ by more than ±2 % for torque and ±2 % for rotational speed from the values declared by the component manufacturer in accordance with point 4.2.5.1 over the whole period of t_{0_maxP}.

Where the values declared by the component manufacturer are outside the tolerances defined in the first paragraph of this point, the procedures laid down in points 4.2.5.1, 4.2.5.2 and in this point shall be repeated with different values for the maximum output torque of the UUT and/or the duration t_{0_maxP}.

The average of the actual measured values over the period of t_{0_maxP} calculated for the different signals of rotational speed, torque and DC input voltage to the inverter (or DC/DC converter if applicable) shall be used as final values for characterisation of the overload point. Additionally, the average of the actual measured electric power to or from the inverter (or DC/DC converter if applicable) over the period of t_{0_maxP} shall be calculated.

4.2.6 EPMC test

The EPMC test measures the electric power to or from the inverter (or DC/DC converter if applicable) for different operating points of the UUT.

4.2.6.1 Preconditioning

The UUT shall be conditioned (i.e. without operating the system) at an ambient temperature of 25 ±10 °C for a minimum of two hours. If this test is performed directly consecutive to any other test run performed in accordance with this Annex the conditioning for a minimum of two hours may be omitted or shortened as long as the UUT stays within the testcell with the ambient temperature in the testcell kept within 25 ±10 °C.

4.2.6.2 Operating points to be measured

For IEPC with multispeed gearbox the setpoints for rotational speed in accordance with point 4.2.6.2.1 and for torque accordance with point 4.2.6.2.2 are determined for each single forward gear.

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4.2.6.2.1 Setpoints for rotational speed

The setpoints for either a standalone electric machine system or an IEPC with no shiftable gears shall be defined in accordance with the following provisions:

(a) As setpoints for rotational speed of the UUT the same setpoints used for the measurement performed in accordance with point 4.2.2.2 for the respective voltage level shall be used.

(b) The speed setpoint for the maximum 30 minutes continuous torque verification performed in accordance with point 4.2.4.2 for the respective voltage level shall be used in addition to the setpoints defined in subpoint (a) above.

(c) Further speed setpoints may be defined in addition to the setpoints defined in subpoints (a) and (b) above.

In the case of an IEPC with multispeed gearbox, a separate dataset of setpoints for rotational speed of the UUT shall be defined for each single forward gear based on the following provisions:

(d) The rotational speed setpoints for the gear with the gear ratio closest to 1 (where the gear ratios of two gears have the same distance to a gear ratio of 1, the test shall be performed only for the gear with the higher of the two gear ratios) determined in accordance with subpoints (a) to (c), $n_{k,gear\_iCT1}$, shall be used as basis for the further step in subpoint (e).

(e) These rotational speed setpoints shall be converted to the respective setpoints for all other gears by the following equation:

$$n_{k,gear} = n_{k,gear\_iCT1} \times i_{gear\_iCT1} / i_{gear}$$

where:

$n_{k,gear}$ = rotational speed setpoint k for a specific gear

(where k = 1, 2, 3, …, maximum number of rotational speed setpoints)

(where gear = 1, …, highest gear number)

$n_{k,gear\_iCT1}$ = rotational speed setpoint k for the gear with the gear ratio closest to 1 in accordance with subpoint (d)

(where k = 1, 2, 3, …, maximum number of rotational speed setpoints)

i_{gear} = gear ratio of a specific gear [-]

(where gear = 1, …, highest gear number)

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i_{gear_iCT1} = gear ratio of the gear with the gear ratio closest to 1

in accordance with subpoint (d) [-]

4.2.6.2.2 Setpoints for torque

The setpoints for either a standalone electric machine system or an IEPC with no shiftable gears shall be defined in accordance with the following provisions:

(a) At least 10 setpoints for torque of the UUT shall be defined for the measurement, located both on the positive (i.e. driving) and negative (i.e. braking) torque side. The lowest and highest torque setpoint shall be defined based on the minimum and maximum torque limits determined in accordance with point 4.2.2.4 for the respective voltage level, where the lowest torque setpoint shall be the overall minimum torque, $T_{min\_overall}$, and the highest torque setpoint shall be the overall maximum torque, $T_{max\_overall}$, determined from these values.

(b) The remaining 8 or more different torque setpoints shall be located between the lowest and highest torque setpoint. The interval between two adjacent torque setpoints shall not be larger than 22.5 % of the overall maximum torque of the UUT determined in accordance with point 4.2.2.4 for the respective voltage level.

(c) The limit value for positive torque at a particular rotational speed shall be the maximum torque limit at this particular rotational speed setpoint determined in accordance with point 4.2.2.4 for the respective voltage level, minus 5 % of $T_{max\_overall}$. All torque setpoints at a particular rotational speed setpoint that are located higher than the limit value for positive torque at this particular rotational speed shall be replaced by one single target torque setpoint located at the maximum torque limit at this particular rotational speed setpoint.

(d) The limit value for negative torque at a particular rotational speed shall be the minimum torque limit at this particular rotational speed setpoint determined in accordance with point 4.2.2.4 for the respective voltage level, minus 5 % of $T_{min\_overall}$. All torque setpoints at a particular rotational speed setpoint that are located lower than the limit value for negative torque at this particular rotational speed shall be replaced by one single target torque setpoint located at the minimum torque limit at this particular rotational speed setpoint.

(e) Minimum and maximum torque limitations for a particular rotational speed setpoint shall be determined based on the data generated in accordance with point 4.2.2.4 for the respective voltage level, by using linear interpolation.

In the case of an IEPC with multispeed gearbox, a separate dataset of setpoints for torque of the UUT shall be defined for each single gear based on the following provisions:

(f) The torque setpoints for the gear with the gear ratio closest to 1 (where the gear ratios of two gears have the same distance to a gear ratio of 1, the test shall be performed only for the gear with the higher of the two gear ratios) determined in accordance with subpoints (a) to (e), $T_{j,gear\_iCT1}$, shall be used as basis for the further step in subpoints (g) and (h).

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(g) These torque setpoints shall be converted to the respective setpoints for all other gears by the following equation:

$$T_{j,gear} = T_{j,gear\_iCT1} / i_{gear\_iCT1} \times i_{gear}$$

where:

$T_{j,gear}$ = torque setpoint j for a specific gear

(where j = 1, 2, 3, …, maximum number of torque setpoints)

(where gear = 1, …, highest gear number)

$Tj,_{gear\_iCT1}$ = torque setpoint j for the gear with the gear ratio closest to 1

in accordance with subpoint (f)

(where j = 1, 2, 3, …, maximum number of torque setpoints)

i_{gear} = gear ratio of a specific gear [-]

(where gear = 1, …, highest gear number)

i_{gear_iCT1} = gear ratio of the gear with the gear ratio closest to 1

in accordance with subpoint (f) [-]

(h) All torque setpoints $T_{j,gear}$ that have an absolute value higher than 10 kNm shall not be required to be measured during the actual test run performed in accordance with point 4.2.6.4.

4.2.6.3 Signals to be measured

Under the operating points specified in accordance with point 4.2.6.2 the electric power to or from the inverter (or DC/DC converter if applicable) and the output torque and speed of the UUT shall be measured.

4.2.6.4 Test sequence

The test sequence consists of steady state setpoints with defined rotational speed and torque at each setpoint in accordance with point 4.2.6.2.

In case an unforeseen interruption occurs, the test sequence may be continued under the following provisions:

— The UUT stays within the testcell, with the ambient temperature in the testcell kept within 25 ±10 °C;

— Before continuing the test the UUT shall be run on the bench for warm-up according to the recommendations of the component manufacturer.

— After the warm-up the test sequence shall be continued at the next lower rotational speed setpoint to the rotational speed setpoint where the interruption occurred.

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— At the next lower rotational speed setpoint the test sequence described by subpoint (a) to (m) further below shall be followed, but only for preconditioning purposes without recording any measurement data.

— Recording of measurement data shall be done, starting from the first operating point at the rotational speed setpoint where the interruption occurred.

In the case of an IEPC, the following provisions shall apply:

— The test sequence shall be performed for each single gear sequentially starting from the gear with the highest gear ratio to be continued with the gears in descending order of gear ratio.

— All setpoints within a dataset for a specific gear determined in accordance with point 4.2.6.2 shall be completed before the measurement is continued in a different gear.

— It is allowed to interrupt the test after completion of measurement for each specific gear.

— The use of different torque meters is allowed.

Just before beginning the test at the first setpoint, the UUT shall be run on the bench for warm-up in accordance with the recommendations of the component manufacturer. The first rotational speed setpoint for the actual measured gear for starting the EPMC test is defined at the lowest rotational speed setpoint.

The remaining setpoints for the actual measured gear shall be applied in the following order:

(a) The first operating point at a particular rotational speed setpoint is defined at the highest torque at this specific speed.

(b) The next operating point shall be set at the same speed and the lowest positive (i.e. driving) torque setpoint.

(c) The next operating point shall be set at the same speed and the second highest positive (i.e. driving) torque setpoint.

(d) The next operating point shall be set at the same speed and the second lowest positive (i.e. driving) torque setpoint.

(e) This order of switching from the remaining highest to the remaining lowest torque setpoint shall be continued until all positive (i.e. driving) torque setpoints at a particular rotational speed setpoint are measured.

(f) Before continuing with step (g) the UUT may be cooled down in accordance with the component manufacturer's recommendations by running at a particular setpoint defined by the component manufacturer.

(g) Then measurement of the negative (i.e. braking) torque setpoints at the same rotational speed setpoint shall be performed starting at the lowest torque at this specific speed.

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(h) The next operating point shall be set at the same speed and the highest negative (i.e. braking) torque setpoint.

(i) The next operating point shall be set at the same speed and the second lowest negative (i.e. braking) torque setpoint.

(j) The next operating point shall be set at the same speed and the second highest negative (i.e. braking) torque setpoint.

(k) This order of switching from the remaining lowest to the remaining highest torque setpoint shall be continued until all negative (i.e. braking) torque setpoints at a particular rotational speed setpoint are measured.

(l) Before continuing with step (m) the UUT may be cooled down in accordance with the component manufacturer's recommendations by running at a particular setpoint defined by the component manufacturer.

(m) The test shall continue at the next higher rotational speed setpoint by repeating steps (a) to (m) of the defined test sequence above until all rotational speed setpoints for the actual measured gear were completed.

All operating points shall be held for an operating time of at least 5 seconds. During this operating time the rotational speed of the UUT shall be held at the rotational speed setpoint within a tolerance of ±1 % or 20 rpm whatever is larger. Additionally, during this operating time, except for the highest and lowest torque setpoint at each rotational speed setpoint, the torque shall be held at the torque setpoint within a tolerance of ±1 % or ±5 Nm whatever is larger of the value of the torque setpoint.

The electric power to or from the inverter (or DC/DC converter if applicable), the output torque and rotational speed of the UUT shall be recorded as average value over the last two seconds of the operating time.

4.3. Post-processing of measurement data of the UUT

4.3.1 General provisions for post-processing

All post-processing steps defined in points 4.3.2 to 4.3.6 shall be performed for the datasets measured for the two different voltage levels in accordance with point 4.1.3 separately.

4.3.2 Maximum and minimum torque limits

The data for maximum and minimum torque limits determined in accordance with point 4.2.2.4 shall be extended by means of linear extrapolation (using the two closest points) to zero rotational speed and to the maximum operating speed of the UUT as declared by the component manufacturer in the event that the recorded measurement data does not cover these ranges.

4.3.3 Drag curve

The data for the drag curve determined in accordance with point 4.2.3 shall be modified in accordance with the following provisions:

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(1) Where the electric power supply to the inverter (or DC/DC converter if applicable) was set inactive or disconnected, the respective values for electric power to the inverter (or DC/DC converter if applicable) shall be set to 0.

(2) Where the output shaft of the UUT was not connected to the load machine (i.e. dynamometer), the respective torque values shall be set to 0.

(3) The data modified in accordance with points (1) and (2) above shall be extended by means of linear extrapolation to the maximum operating speed of the UUT as declared by the component manufacturer where the recorded measurement data does not cover these ranges.

(4) The values of electric power to the inverter (or DC/DC converter if applicable) modified in accordance with points (1) to (3) above shall be seen as virtual mechanical loss power. These values of virtual mechanical loss power shall be converted to virtual drag torque with the respective rotational speed of the output shaft of the UUT.

(5) At each setpoint of rotational speed of the output shaft of the UUT in the data modified in accordance with points (1) to (3) above, the value of virtual drag torque determined in accordance with point (4) above shall be added to the actual torque of the load machine (i.e. dynamometer) to define the total drag torque of the UUT as function of rotational speed.

(6) The values of the total drag torque of the UUT at the lowest rotational speed setpoint, determined from the data modified in accordance with point (5) above, shall be copied to a new entry at 0 rpm rotational speed and added to the data modified in accordance with point (5) above.

4.3.4 EPMC

The data for the EPMC determined in accordance with point 4.2.6.4 shall be extended in accordance with the following provisions for each forward gear measured separately:

(1) The values of all data pairs for output torque and eletric inverter power determined at the lowest rotational speed setpoint shall be copied to a new entry at zero rotational speed.

(2) The values of all data pairs for output torque and eletric inverter power determined at the highest rotational speed setpoint shall be copied to a new entry at the highest rotational speed setpoint times 1.05.

(3) If at a specific rotational speed setpoint (including the newly introduced data in points 1 and 2 above) a torque setpoint determined in accordance with the provisions of point 4.2.6.2.2 in subpoints (a) to (g) was ommited for the actual measurement in accordance with subpoint (h) of point 4.2.6.2.2 a new data point shall be calculated based on the following provisions:

(a) Rotational speed: using the value of the omitted setpoint for the rotational speed

(b) Torque: using the value of the omitted setpoint for torque

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(c) Inverter power: calculating a new value by means of linear extrapolation where the slope of the least squares linear regression line determined based on the three actually measured torque points located closest to the torque value from subpoint (b) above for the corresponding rotational speed setpoint shall be applied.

(d) For positive torque values, extrapolated values of inverter power resulting in values lower than the measured one at the actually measured torque point located closest to the torque value from subpoint (b) above shall be set to the inverter power actually measured at the torque point located closest to the torque value from subpoint (b) above.

(e) For negative torque values, extrapolated values of inverter power resulting in values higher than the measured one at the actually measured torque point located closest to the torque value from subpoint (b) above shall be set to the inverter power actually measured at the torque point located closest to the torque value from subpoint (b) above.

(4) At each rotational speed setpoint (including the newly introduced data in points 1 to 3 above) a new data point shall be calculated based on the data at the highest torque setpoint in accordance with the following rules:

(a) Rotational speed: using the same value for the rotational speed

(b) Torque: using the value for torque multiplied by a factor of 1,05

(c) Inverter power: calculating a new value in such a way that the efficiency defined as the ratio of mechanical power to inverter power stays constant

(5) At each rotational speed setpoint (including the newly introduced data in points 1 to 3 above) a new data point shall be calculated based on the data at the lowest torque setpoint in accordance with the following rules:

(a) Rotational speed: using the same value for the rotational speed

(b) Torque: using the value for torque multiplied by a factor of 1.05

(c) Inverter power: calculating a new value in such a way that the efficiency defined as the ratio of inverter power to mechanical power stays constant

4.3.5 Overload characteristics

From the data for the overload characteristics determined in accordance with point 4.2.5.3 an efficiency figure shall be determined by dividing the average mechanical output power over the period of t_{0_maxP} by the average electric power to or from the inverter (or DC/DC converter if applicable) over the period of t_{0_maxP}.

4.3.6 Maximum 30 minutes continuous torque

From the data determined in accordance with point 4.2.4.3 an efficiency figure shall be determined by dividing the average 30 minutes continuous power by the average electric power to or from the inverter (or DC/DC converter if applicable).

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From the measurement data for the maximum 30 minutes continuous torque determined in accordance with point 4.2.4.2 the following average values shall be determined from the time-resolved values over the 1 800-second measurement period for each cooling circuit with connection to an external heat exchanger separately:

— cooling power

— coolant temperature at the inlet of the cooling circuit of the UUT

The cooling power shall be determined based on the specific heat capacity of the coolant, the coolant massflow and the temperature difference over the test bed heat exchanger on the side of the UUT.

4.4 Special provisions for testing of IHPCs Type 1

IHPCs Type 1 are virtually split into two separate components for handling in the simulation tool, i.e. an electric machine system and a transmission. Therefore, two separate component data sets shall be determined by following the provisions described in this point.

For component testing of IHPCs Type 1, points 4.1 to 4.2 of this Annex shall apply.

For an IHPC Type 1 the torque and speed shall be measured at the output shaft of the system (i.e. the output side of the gearbox towards the wheels of the vehicle).

The definition of families in accordance with Appendix 13 shall not be allowed for IHPCs Type 1. Therefore, omission of test runs is not allowed and all test runs described in point 4.2 shall be performed for one specific IHPC Type 1. Notwithstanding these provisions, the test of the drag curve in accordance with point 4.2.3 shall be omitted for IHPCs Type 1.

Generating input data for IHPCs Type 1 based on standard values shall not be allowed.

4.4.1 Test runs to be performed for IHPCs Type 1

4.4.1.1 Test runs to determine the total system characteristics

This subpoint describes the details for determining the characteristics of the complete IHPC Type 1 including the losses of the gearbox part within the system.

The following test runs shall be performed in accordance with the provisions defined for IEPC with multispeed gearbox in the respective points. For all of these test runs, the input shaft for feeding propulsion torque into the system shall be either disconnected and rotating freely or shall be fixed without rotating.

Table 2a

Overview of test runs to be performed for IHPC Type 1

Test run	Reference to point
Maximum and minimum torque limits	4.2.2
Maximum 30 minutes continuous torque	4.2.4
Overload characteristics	4.2.5
EPMC	4.2.6

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Due to the applicability of the provisions defined for IEPC with multispeed gearbox to IHPCs Type 1, the EPMC shall be measured for each single forward gear in accordance with point 4.2.6.2.

4.4.1.2 Test runs to determine the losses of the gearbox part within the system

This subpoint describes the details for determining the losses of the gearbox part within the system.

Therefore, the system shall be tested in accordance with the provisions in point 3.3 of Annex VI. Notwithstanding these provisions, the following provisions shall be applied:

— The input shaft for feeding propulsion torque into the system shall be connected to and driven by a dynamometer in accordance with the provisions in point 3.3 of Annex VI.

— The power supply from the electric DC powersource to the inverter(s) (or DC/DC converter(s) if applicable) shall be disconnected. In order to allow this disconnection without any parts of the system being damaged, the system may be modified in a way that dummy magnets or dummy rotors are used in the electric machine(s) part for the measurement.

— The torque range as defined in point 3.3.6.3 of Annex VI shall be extended to cover also negative torque values in such a way that the same torque setpoints from the positive side are measured also with a negative algebraic sign.

4.4.2 Post-processing of measurement data of IHPCs Type 1

For post-processing of measurement data of IHPCs Type 1, all provisions as laid down in point 4.3 shall apply unless stated otherwise.

4.4.2.1 Post-processing of data regarding total system characteristics

All measurement data determined in accordance with point 4.4.1.1 shall be handled in accordance with the provisions as laid down in points 4.3.1 to 4.3.6. The provisions of point 4.3.3 shall be omitted since measurement of the drag curve in accordance with point 4.2.3 is not performed for IHPCs Type 1. Where there are specific provisions defined for IEPC with multispeed gearbox in the respective points, such specific provisions shall be applied.

4.4.2.2 Post-processing of data regarding losses of the gearbox part within the system

All measurement data determined in accordance with point 4.4.1.2 shall be handled in accordance with the provisions as laid down in point 3.4 of Annex VI. Notwithstanding these provisions, the following provisions shall be applied:

— The provisions as laid down in points 3.4.2 to 3.4.5 of Annex VI shall be applied analogously also for negative torque values.

— The provisions as laid down in point 3.4.6 of Annex VI shall not be applied.

▼**M3**

4.4.2.3 Post-processing of data to derive the specific data of the virtual electric machine system

In order to determine the component data of the virtual electric machine system the following steps shall be applied. The following post-processing steps shall be omitted for the two efficiency figures determined in accordance with points 4.3.5 and 4.3.6 since these efficiency figures only serve for assessment of conformity of the certified CO_2 emissions and fuel consumption related properties.

(a) All speed and torque values of the measurement data handled in accordance with point 4.4.2.1 shall be converted from the output shaft to the input shaft of the IHPC Type 1 in accordance with the following equations. Where the same test run was performed for several gears, the conversion shall be performed for each gear separately.

$$n_{EM,virt} = n_{output} \times i_{gbx}$$

$$T_{EM,virt} = T_{Output} \times \frac{1}{i_{gbx}} + T_{loss,gbx}\left(n_{EM,virt}, T_{Output} \times \frac{1}{i_{gbx}}, gear\right)$$

where:

$n_{EM,virt}$ = rotational speed of the virtual electric machine system referring to the input shaft of the IHPC Type 1 [1/min]

n_{output} = measured rotational speed at the output shaft of the IHPC Type 1 [1/min]

i_{gbx} = ratio of rotational speed at the input shaft over the rotational speed at the output shaft of the IHPC Type 1 for a specific gear engaged during the measurement [-]

$T_{EM,virt}$ = torque of the virtual electric machine system referring to the input shaft of the IHPC Type 1 [Nm]

T_{output} = measured torque at the output shaft of the IHPC Type 1 [Nm]

$T_{loss,gbx}$ = torque loss depending on rotational speed and torque at the input shaft of the IHPC Type 1 [Nm]. It shall be calculated by means of two-dimensional linear interpolation from the loss maps of the gearbox determined in accordance with point 4.4.2.2 for the respective gear.

gear = specific gear engaged during the measurement [-]

▼M3

(b) The electric power maps determined for each forward gear in accordance with point 4.4.2.1 and converted to the input shaft in accordance with subpoint (a) of point 4.4.2.3 shall be used as basis for the following calculations. All values of electric inverter power of these electric power maps shall be converted to the respective maps for the virtual electric machine system by deducting the losses of the gearbox part in accordance with the following equation:

$$P_{el,virt}(n_{EM,virt}, T_{EM,virt}) = P_{el,meas}(n_{EM,virt}, T_{EM,virt}) - T_{loss,gbx}(n_{EM,virt}, T_{EM,virt},\ gear) \times n_{EM,virt}$$

where:

$P_{el,virt}$	electric inverter power of the virtual electric machine system [W]
$n_{EM,virt}$	rotational speed of the virtual electric machine system referring to the input shaft of the IHPC Type 1 determined in accordance with subpoint (a) of point 4.4.2.3 [1/min]
$T_{EM,virt}$	torque of the virtual electric machine system referring to the input shaft of the IHPC Type 1 determined in accordance with subpoint (a) of point 4.4.2.3 [Nm]
$P_{el,meas}$	measured electric inverter power [W]
$T_{loss,gbx}$	torque loss depending on rotational speed and torque at the input shaft of the IHPC Type 1 [Nm]. It shall be calculated by means of two-dimensional linear interpolation from the loss maps of the gearbox determined in accordance with point 4.4.2.2 for the respective gear.
gear	specific gear engaged during the measurement [-]

(c) The drag torque values of the virtual electric machine system shall be specified at the same rotational speed setpoints, $n_{EM,virt}$, referring to the input shaft of the IHPC Type 1 as used for the definition of the maximum and minimum torque curve of the virtual electric machine system. Each single value of drag torque in Nm indicated at the different rotational speed setpoints shall be set to zero.

(d) The rotational inertia of the virtual electric machine system shall be calculated by converting the inertia value(s) of the actual electric machine(s) determined in accordance with point 8 of Appendix 8 of this Annex to the corresponding value of rotational inertia referring to the input shaft of the IHPC Type 1.

4.4.3 Generation of input data for the simulation tool

Since IHPCs Type 1 are virtually split into two separate components for handling in the simulation tool, separate component input data shall be determined for an electric machine system and a transmission. The certification number indicated in the input data shall be the same for both components, electric machine system and transmission.

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4.4.3.1 Input data of the virtual electric machine system

The input data for the virtual electric machine system shall be generated in accordance with the definitions for the electric machine system in Appendix 15 based on the final data resulting from following the provisions in point 4.4.2.3.

4.4.3.2 Input data of the virtual transmission

The input data for the virtual transmission shall be generated in accordance with the definitions for the transmission in Table 1 to Table 3 of Appendix 12 of Annex VI based on the final data resulting from following the provisions in point 4.4.2.2. The value of the parameter 'TransmissionType' in Table 1 shall be set to 'IHPC Type 1'.

5. Testing of battery systems or representative battery subsystems

The battery UUT thermal conditioning device and the corresponding thermal conditioning loop at the test bench equipment shall be operational to satisfy the battery UUT thermal conditioning performances, according to the vehicle application and shall enable the test bench equipment to perform the requested test procedure within the battery UUT operational limits

5.1 General provisions

Battery UUT components may be distributed in different devices within the vehicle.

The battery UUT shall be controlled by the BCU, the test bench equipment shall follow the operational limits provided by the BCU via bus communication. The battery UUT thermal conditioning device and the corresponding thermal conditioning loop at the test bench equipment shall be operational in accordance with the controls by the BCU, unless otherwise specified in the given test procedure. The BCU shall enable the test bench equipment to perform the requested test procedure within the battery UUT operational limits. If necessary, the BCU program shall be adapted by the component manufacturer for the requested test procedure but within the operational and safety limits of the battery UUT.

5.1.1 Conditions for thermal equilibration

Thermal equilibration is reached if during a period of 1 hour the deviations between cell temperature as specified by the component manufacturer and temperature of all cell temperature measuring points are lower than ±7 K.

5.1.2 Sign conventions

5.1.2.1 Current

Measured values of current shall have a positive sign for discharging and a negative sign for charging.

5.1.3 Reference location for ambient temperature

The ambient temperature shall be measured within a distance of 1 m to the battery UUT at a point indicated by the component manufacturer.

5.1.4 Thermal conditions

Battery testing temperature, i.e. the target operating temperature of the battery UUT, shall be specified by the component manufacturer. The temperature of all cell temperature measuring points shall be within the limits specified by the component manufacturer during all test runs performed.

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For battery UUT with liquid conditioning (i.e. heating or cooling), the temperature of the conditioning fluid shall be recorded at the battery UUT inlet and must be maintained within ±2 K of a value specified by the component manufacturer.

For air cooled battery UUT, the temperature of the battery UUT at a point indicated by the component manufacturer shall be kept within +0/-20 K of the maximum value specified by the component manufacturer.

For all test runs performed the available cooling and/or heating power on the testbench shall be limited to a value declared by the component manufacturer. This value shall be recorded together with the test data.

The available cooling and/or heating power on the testbench shall be determined based on the following procedures and recorded together with the actual component test data:

(1) For liquid conditioning from the massflow of the conditioning fluid and the temperature difference over the heat exchanger on the side of the battery UUT.

(2) For electric conditioning from the voltage and current. The component manufacturer may modify the electric connection of this conditioning unit for the certification of the battery UUT to enable a measurement of the battery UUT characteristics without considering the electric power required for conditioning (e.g. if the conditioning is directly implemented and connected within the battery UUT). Notwithstanding these provisions, the required electric cooling and/or heating power externally provided to the battery UUT by a conditioning unit shall be recorded.

(3) For other types of conditioning based on good engineering judgement and discussion with the type approval authority.

5.2 Preparation cycles

The battery UUT shall be conditioned by performing maximum five cycles of full discharging followed by full charging in order to ensure stabilisation of the system's performance before the actual testing starts.

Consecutive cycles of full discharging followed by full charging shall be performed at the component manufacturer defined operational set temperature until the 'preconditioned' status is reached. The criterion for a 'preconditioned' battery UUT is that the discharged capacity during two consecutive discharges does not change by a value greater than 3 % of the rated capacity or that five repetitions were performed.

The voltage of the battery UUT shall not fall below the minimum voltage recommended by the component manufacturer at the end of the discharge (the minimum voltage is the lowest voltage under discharge without irreversible damage done to the battery UUT). The termination criteria for the full discharging and the full charging cycles shall be defined by the component manufacturer.

5.2.1 Current levels in preparation cycles for HPBS

Discharging shall be performed at a current of 2C, charging shall be performed in accordance with the recommendations of the component manufacturer.

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5.2.2 Current levels in preparation cycles Preconditioning for HEBS

Discharging shall be performed at a current of 1/3C, charging shall be performed in accordance with the recommendations of the component manufacturer.

5.3 Standard cycle

The purpose of a standard cycle (SC) is to ensure the same initial condition for each dedicated test of a battery UUT, as well as the charged energy for COP purposes in accordance with Appendix 12. It shall be performed at the component manufacturer defined operational set temperature.

5.3.1 Standard cycle for HPBS

The SC for HPBS shall consist of the following events in consecutive order: a standard discharge, a rest period, a standard charge and a second rest period.

The standard discharge procedure shall be performed at a current of 1C down to the minimum SOC in accordance with the specifications of the component manufacturer.

The rest period shall start directly after the end of discharge and shall last for 30 minutes.

The standard charge procedure shall be performed in accordance with the specifications of the component manufacturer regarding criteria for end of charge as well as applicable time limits for the overall charging procedure.

The second rest period shall start directly after the end of charge and shall last for 30 minutes.

5.3.2 Standard cycle for HEBS

The SC for HEBS shall consist of the following events in consecutive order: a standard discharge, a rest period, a standard charge and a second rest period.

The standard discharge procedure shall be performed at a current of 1/3C down to the minimum SOC in accordance with the specifications of the component manufacturer.

The rest period shall start directly after the end of discharge and shall last for 30 minutes.

The standard charge procedure shall be performed in accordance with the specifications of the component manufacturer regarding criteria for end of charge as well as applicable time limits for the overall charging procedure.

The second rest period shall start directly after the end of charge and shall last for 30 minutes.

5.4 Test runs to be performed

Before any test runs in accordance with this point are performed the battery UUT shall be subjected to the provisions in accordance with point 5.2.

5.4.1 Test procedure for rated capacity

This test measures the rated capacity of the battery UUT in Ah at constant current discharge rates.

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5.4.1.1 Signals to be measured

The following signals shall be recorded during preconditioning, standard cycles performed and the actual test run:

— Charge/Discharge current at the terminals of the battery UUT

— Voltage across the terminals of the battery UUT

— Temperatures of all measuring points of the battery UUT

— Ambient temperature in the testbench

— Heating or cooling power for battery UUT

5.4.1.2 Test run

After the battery UUT was fully charged in accordance with the specifications of the component manufacturer and thermal equilibration in accordance with point 5.1.1 was reached, a standard cycle in accordance with point 5.3 shall be performed.

The actual test run shall start within a period of 3 hours after the end of the standard cycle, otherwise the standard cycle shall be repeated.

The actual test run shall be performed at RT and consist of a constant current discharge at the following discharge rates:

— For HPBS to the component manufacturer's rated 1 C capacity in Ah

— For HEBS to the component manufacturer's rated 1/3C capacity in Ah

All discharge tests shall be terminated at the minimum conditions in accordance with the specifications of the component manufacturer.

5.4.1.3 Interpretation of results

The capacity in Ah obtained from the integrated battery current over time during the actual test run in accordance with point 5.4.1.2 shall be used as value for the rated capacity.

5.4.1.4 Data to be reported

The following data shall be reported:

— Rated capacity determined in accordance with point 5.4.1.3

— Average values over the actual test run of all signals recorded in accordance with point 5.4.1.1

For the purpose of conformity of production testing, also the following values shall be calculated:

— The total charged energy, E_{cha}, from 20 to 80 % SOC during the standard cycle performed prior to the actual test run.

— The total discharged energy, E_{dis}, from 80 to 20 % SOC during the actual test run.

All SOC values used shall be calculated based on the actual measured rated capacity determined in accordance with point 5.4.1.3.

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The round trip efficiency η_{BAT} shall be calculated by dividing the total discharged energy, E_{dis}, by the total charged energy, E_{cha} and reported in the information document in accordance with Appendix 5.

5.4.2 Test procedure for open circuit voltage, internal resistance and current limits

This test determines the ohmic resistance for discharge and charge conditions as well as the OCV of the battery UUT as a function of SOC. In addition, the maximum current for discharging and charging as declared by the component manufacturer shall be verified.

5.4.2.1 General provisions for testing

All SOC values used shall be calculated based on the actual measured rated capacity determined in accordance with point 5.4.1.3.

Only where the battery UUT reaches the discharge voltage limit during discharge, shall the current be reduced such that the battery UUT terminal voltage is maintained at the discharge voltage limit throughout the whole discharge pulse.

Only where the battery UUT reaches during charging the charge voltage limit, shall the current be reduced such that the battery UUT terminal voltage is maintained at the charge voltage limit throughout the whole regenerative charge pulse.

If the test equipment cannot provide the current value with the requested accuracy of ±1 % of the target value within 100 ms after a change in the current profile, the respective recorded data shall be discarded and no related values for open circuit voltage and internal resistance shall be calculated from this data.

If the operational limits provided by the BCU via bus communication demand the current to be reduced in order to stay within the operational limits of the battery UUT the test bench equipment shall reduce the respective target current in accordance with the demands of the BCU.

5.4.2.2 Signals to be measured

The following signals shall be recorded during preconditioning and the actual test run:

— Discharge current at the terminals of the battery UUT

— Voltage across the terminals of the battery UUT

— Temperatures of all measuring points of the battery UUT

— Ambient temperature in the testbench

— Heating or cooling power for battery UUT

5.4.2.3 Test run

5.4.2.3.1 Preconditioning

After the battery UUT was fully charged in accordance with the specifications of the component manufacturer and thermal equilibration in accordance with point 5.1.1 was reached, a standard cycle in accordance with point 5.3 shall be performed.

Within a period of 1 to 3 hours after the end of the standard cycle, the actual test run shall be started. Otherwise, the procedure in the preceding paragraph shall be repeated.

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5.4.2.3.2 Test procedure

For HPBS, the test shall be performed at five different SOC levels: 80, 65, 50, 35 and 20 %.

For HEBS, the test shall be performed at five different SOC levels: 90, 70, 50, 35 and 20 %.

At the last step at 20 % SOC the component manufacturer may reduce the maximum discharge current of the battery UUT in order for the SOC to stay above the minimum SOC, in accordance with the specifications of the component manufacturer and avoid a deep discharge.

Before the beginning of the actual test runs at each SOC level, the battery UUT shall be preconditioned in accordance with point 5.4.2.3.1.

In order to reach the required SOC levels for testing from the initial condition of the battery UUT, it shall be discharged at a constant current rate of 1C for HPBS and of 1/3C for HEBS followed by a rest period of 30 minutes before the next measurement starts.

The component manufacturer shall prior to the test declare the maximum charge and discharge current at each different SOC level that can be applied throughout the length of the respective time increment of the current pulse defined in accordance with Table 3 for HPBS and Table 4 for HEBS.

The actual test run shall be performed at RT and shall consist of the current profile in accordance with Table 3 for HPBS and in accordance with Table 4 for HEBS.

Table 3

Current profile for HPBS

Time increment [s]	Time cumulative [s]	Target current
0	0	0
20	20	$I_{dischg\_max}/3^3$
40	60	0
20	80	$I_{chg\_max}/3^3$
40	120	0
20	140	$I_{dischg\_max}/3^2$
40	180	0
20	200	$I_{chg\_max}/3^2$
40	240	0
20	260	$I_{dischg\_max}/3$
40	300	0
20	320	$I_{chg\_max}/3$
40	360	0
20	380	I_{dischg_max}
40	420	0
20	440	I_{chg_max}
40	480	0

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Table 4

Current profile for HEBS

Time increment [s]	Time cumulative [s]	Target current
0	0	0
120	120	$I_{dischg\_max}/3^3$
40	160	0
120	280	$I_{chg\_max}/3^3$
40	320	0
120	440	$I_{dischg\_max}/3^2$
40	480	0
120	600	$I_{chg\_max}/3^2$
40	640	0
120	760	$I_{dischg\_max}/3$
40	800	0
120	920	$I_{chg\_max}/3$
40	960	0
120	1080	I_{dischg_max}
40	1120	0
120	1240	I_{chg_max}
40	1280	0

Where

I_{dischg_max} is the absolute value of the maximum discharge current specified by the component manufacturer at the specific SOC level that can be applied throughout the length of the respective time increment of the current pulse

I_{chg_max} is the absolute value of the maximum charge current specified by the component manufacturer at the specific SOC level that can be applied throughout the length of the respective time increment of the current pulse

The voltage at time zero of the test run before the first change in target current occurs, i.e. V_0, shall be measured as average value over 100 ms.

For HPBS the following voltages and currents shall be measured:

(1) For each different discharging and charging current pulse level specified in Table 3, the voltage under zero current as average value over the last second before the change in target current occurs, i.e. Vd_{start} for discharging and Vc_{start} for charging, shall be measured.

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(2) For each different discharging current pulse level specified in Table 3, the voltage at 2, 10 and 20 seconds after the change in target current occurs (Vd_2, Vd_{10}, Vd_{20}) and the corresponding current (Id_2, Id_{10}, and Id_{20}) shall be measured as average value over 100ms.

(3) For each different charging current pulse level specified in Table 3, the voltage at 2, 10 and 20 seconds after the change in target current occurs (Vc_2, Vc_{10}, Vc_{20}) and the corresponding current (Ic_2, Ic_{10}, and Ic_{20}) shall be measured as average value over 100 ms.

Table 5 gives an overview of voltage and current values to be measured over time after the change in target current occurs for HPBS.

Table 5

Voltage measurement points for each different level of a current pulse (discharging and charging) for HPBS

Time after the change in target current occurs [s]	Discharging (D) or charging (C)	Voltage	Current
2	D	Vd_2	Id_2
10	D	Vd_{10}	Id_{10}
20	D	Vd_{20}	Id_{20}
2	C	Vc_2	Ic_2
10	C	Vc_{10}	Ic_{10}
20	C	Vc_{20}	Ic_{20}

For HEBS the following voltages and currents shall be measured:

(1) For each different discharging and charging current pulse level specified in table 4 the voltage under zero current as average value over the last second before the change in target current occurs, i.e. Vd_{start} for discharging and Vc_{start} for charging, shall be measured.

(2) For each different discharging current pulse level specified in table 4, the voltage at 2, 10 20 and 120 seconds after the change in target current occurs (Vd_2, Vd_{10}, Vd_{20} and Vd_{120}) and the corresponding current (Id_2, Id_{10}, Id_{20} and Id_{120}) shall be measured as average value over 100ms.

(3) For each different charging current pulse level specified in table 4, the voltage at 2, 10, 20 and 120 seconds after the change in target current occurs (Vc_2, Vc_{10}, Vc_{20} and Vc_{120}) and the corresponding current (Ic_2, Ic_{10}, Ic_{20} and Ic_{120}) shall be measured as average value over 100 ms.

Table 6 gives an overview of voltage and current values to be measured over the time after the change in target current occurs for HEBS.

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Table 6

Voltage measurement points for each different level of a current pulse (discharging and charging) for HEBS

Time after the change in target current occurs [s]	Discharging (D) or charging (C)	Voltage	Current
2	D	Vd_2	Id_2
10	D	Vd_{10}	Id_{10}
20	D	Vd_{20}	Id_{20}
120	D	Vd_{120}	Id_{120}
2	C	Vc_2	Ic_2
10	C	Vc_{10}	Ic_{10}
20	C	Vc_{20}	Ic_{20}
120	C	Vc_{120}	Ic_{120}

5.4.2.4 Interpretation of results

The following calculations shall be performed separately for each level of SOC measured in accordance with point 5.4.2.3.

5.4.2.4.1 Calculations for HPBS

(1) For each different discharging current pulse level specified in Table 3, the values for internal resistance shall be calculated from the values of voltage and current measured in accordance with point 5.4.2.3 in accordance with the following equations:

— $R_Id_2 = (Vd_{start} - Vd_2) / Id_2$

— $R_Id_{10} = (Vd_{start} - Vd_{10}) / Id_{10}$

— $R_Id_{20} = (Vd_{start} - Vd_{20}) / Id_{20}$

(2) The internal resistances for discharging R_Id_2_avg, R_Id_{10}_avg, R_Id_{20}_avg shall be calculated as average over all different current pulse levels specified in Table 3 from the individual values calculated under point 1.

(3) For each different charging current pulse level specified in Table 3, the values for internal resistance shall be calculated from the values of voltage and current measured in accordance with point 5.4.2.3 in accordance with the following equations:

— $R_Ic_2 = (Vc_{start} - Vc_2) / Ic_2$

— $R_Ic_{10} = (Vc_{start} - Vc_{10}) / Ic_{10}$

— $R_Ic_{20} = (Vc_{start} - Vc_{20}) / Ic_{20}$

(4) The internal resistances for charging R_Ic_2_avg, R_Ic_{10}_avg, R_Ic_{20}_avg shall be calculated as average over all different current pulse levels specified in Table 3 from the individual values calculated under point 3.

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(5) The overall internal resistances R_{I2}, R_{I10} and R_{I20} shall be calculated as average over the respective values for discharging and charging calculated under points 2 and 4.

(6) The open circuit voltage shall be the value of V_0 measured in accordance with point 5.4.2.3 for the respective SOC level.

(7) The limits for maximum discharging current shall be calculated as average value over 20 seconds at the target current I_{dischg_max} for each level of SOC measured in accordance with point 5.4.2.3.

(8) The limits for maximum charging current shall be calculated as average value over 20 seconds at the target current I_{chg_max} for each level of SOC measured in accordance with point 5.4.2.3. Absolute values of the results shall be reported as final values.

5.4.2.4.2 Calculations for HEBS

(1) For each different discharging current pulse level specified in Table 4, the values for internal resistance shall be calculated from the values of voltage and current measured in accordance with point 5.4.2.3 in accordance with the following equations:

— $R_I d_2 = (Vd_{start} - Vd_2) / Id_2$

— $R_I d_{10} = (Vd_{start} - Vd_{10}) / Id_{10}$

— $R_I d_{20} = (Vd_{start} - Vd_{20}) / Id_{20}$

— $R_I d_{120} = (Vd_{start} - Vd_{120}) / Id_{120}$

(2) The internal resistances for discharging $R_I d_2\_avg$, $R_I d_{10}\_avg$, $R_I d_{20}\_avg$ and $R_I d_{120}\_avg$ shall be calculated as average over all different current pulse levels specified in Table 4 from the individual values calculated under point 1.

(3) For each different charging current pulse level specified in Table 4, the values for internal resistance shall be calculated from the values of voltage and current measured in accordance with point 5.4.2.3 in accordance with the following equations:

— $R_I c_2 = (Vc_{start} - Vc_2) / Ic_2$

— $R_I c_{10} = (Vc_{start} - Vc_{10}) / Ic_{10}$

— $R_I c_{20} = (Vc_{start} - Vc_{20}) / Ic_{20}$

— $R_I c_{120} = (Vc_{start} - Vc_{120}) / Ic_{120}$

(4) The internal resistances for charging $R_I c_2\_avg$, $R_I c_{10}\_avg$, $R_I c_{20}\_avg$ and $R_I c_{120}\_avg$ shall be calculated as average over all different current pulse levels specified in Table 4 from the individual values calculated under point 3.

(5) The overall internal resistances R_{I2}, R_{I10}, R_{I20} and R_{I120} shall be calculated as average over the respective values for discharging and charging calculated under points 2 and 4.

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(6) The open circuit voltage shall be the value of V_0 measured in accordance with point 5.4.2.3 for the respective SOC level.

(7) The limits for maximum discharging current shall be calculated as average value over 120 seconds at the target current I_{dischg_max} for each level of SOC measured in accordance with point 5.4.2.3.

(8) The limits for maximum charging current shall be calculated as average value over 120 seconds at the target current I_{chg_max} for each level of SOC measured in accordance with point 5.4.2.3. Absolute values of the results shall be reported as final values.

5.5. Post-processing of measurement data of the battery UUT

The values of OCV dependent on SOC shall be defined based on the values determined for the different SOC levels in accordance with point 6 of point 5.4.2.4.1 for HPBS and 5.4.2.4.2 for HEBS.

The different values of internal resistances dependent on SOC shall be defined based on the values determined for the different SOC levels in accordance with point 5.4.2.4.1(5) for HPBS and 5.4.2.4.2 for HEBS.

The limits for maximum discharging current and maximum charging current shall be defined based on the values as declared by the component manufacturer prior to the test. If a specific value for the maximum discharging current or maximum charging current determined in accordance with point 5.4.2.4.1(7) and (8) for HPBS and 5.4.2.4.2 for HEBS deviates by more than ±2 % from the value declared by the component manufacturer prior to the test, the respective value determined in accordance with points 5.4.2.4.1(7) and (8) for HPBS and 5.4.2.4.2 for HEBS shall be reported.

6. Testing of capacitor systems or representative capacitor subsystems

6.1 General provisions

Capacitor system components of the capacitor UUT may also be distributed in different devices within the vehicle.

The characteristics for a capacitor are hardly dependent on its state of charge or current, respectively. Therefore, only a single test run is prescribed for the calculation of the model input parameters.

6.1.1 Sign convention for current

Measured values of current shall have a positive sign for discharging and a negative sign for charging.

6.1.2 Reference location for ambient temperature

The ambient temperature shall be measured within a distance of 1 m to the capacitor UUT at a point indicated by the component manufacturer of the capacitor UUT.

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6.1.3 Thermal conditions

Capacitor testing temperature, i.e. the target operating temperature of the capacitor UUT, shall be specified by the component manufacturer. The temperature of all capacitor cell temperature measuring points shall be within the limits specified by the component manufacturer during all test runs performed.

For capacitor UUT with liquid conditioning (i.e. heating or cooling), the temperature of the conditioning fluid shall be recorded at the capacitor UUT inlet and must be maintained within ±2 K of a value specified by the component manufacturer.

For air cooled capacitor UUT, the temperature at a point indicated by the component manufacturer shall be kept within +0/–20 K of the maximum value specified by the component manufacturer.

For all test runs performed the available cooling and/or heating power on the testbench shall be limited to a value declared by the component manufacturer. This value shall be recorded together with the test data.

The available cooling and/or heating power on the testbench shall be determined based on the following procedures and recorded together with the actual component test data:

(1) For liquid conditioning from the massflow of the conditioning fluid and the temperature difference over the heat exchanger on the side of the capacitor UUT.

(2) For electric conditioning from the voltage and current. The component manufacturer may modify the electric connection of this conditioning unit for the certification of the capacitor UUT to enable a measurement of the capacitor UUT characteristics without considering the electric power required for conditioning (e.g. if the conditioning is directly implemented and connected within the capacitor UUT). Notwithstanding these provisions, the required electric cooling and/or heating power externally provided to the capacitor UUT by a conditioning unit shall be recorded.

(3) For other types of conditioning based on good engineering judgement and discussion with the type approval authority.

6.2 Test conditions

(a) The capacitor UUT shall be placed in a temperature controlled test cell. The ambient temperature shall be conditioned at 25 ±10 °C;

(b) The voltage shall be measured at the terminals of the capacitor UUT.

(c) The thermal conditioning system of the capacitor UUT and the corresponding thermal conditioning loop at the test bench equipment shall be fully operational in accordance with the respective controls.

▼M3

(d) The control unit shall enable the test bench equipment to perform the requested test procedure within the capacitor UUT operational limits. If necessary, the control unit program shall be adapted by the capacitor UUT component manufacturer for the requested test procedure.

6.3 Capacitor UUT characteristics test

(a) After fully charging and then fully discharging the capacitor UUT to its lowest operating voltage in accordance with the charging method specified by the component manufacturer, it shall be soaked for at least 2 hours, but no more than 6 hours.

(b) The capacitor UUT temperature at the start of the test shall be 25 ± 2 °C. However, 45 ± 2 °C may be selected by reporting to the type approval or certification authority that this temperature level is more representative for the conditions of the typical application.

(c) After the soak time, a complete charge and discharge cycle in accordance with Figure 2 with a constant current I_{test} shall be performed. I_{test} shall be the maximum allowed continuous current for the capacitor UUT as specified by the component manufacturer.

(d) After a waiting period of at least 30 seconds (t_0 to t_1), the capacitor UUT shall be charged with a constant current I_{test} until the maximum operating voltage V_{max} is reached. Then, the charging shall be stopped and the capacitor UUT shall be soaked for 30 seconds (t_2 to t_3) so that the voltage can settle to its final value V_b before the discharging is started. After that the capacitor UUT shall be discharged with a constant current I_{test} until the lowest operating voltage V_{min} is reached. Afterwards (from t_4 onwards) there shall be another waiting period of at least 30 seconds for the voltage to settle to its final value V_c.

(e) The current and voltage over time, respectively I_{meas} and V_{meas}, shall be recorded at a sampling frequency of at least 10 Hz.

(f) The following characteristic values shall be determined from the measurement (illustrated in Figure 2):

V_a is the no-load voltage right before start of the charge pulse

V_b is the no-load voltage right before start of the discharge pulse

V_c is the no-load voltage after the end of the discharge pulse

$\Delta V(t_1)$, $\Delta V(t_3)$ are the voltage changes directly after applying the constant charging or discharging current I_{test} at the time of t_1 and t_3, respectively. These voltage changes shall be determined by applying a linear approximation to the voltage characteristics as defined in detail A of Figure 2 by usage of the least squares method. Data sampling for the straight line approximation shall start once the change in the gradient calculated from two adjacent data points is smaller than 0.5 % when running in the direction of increasing time signal.

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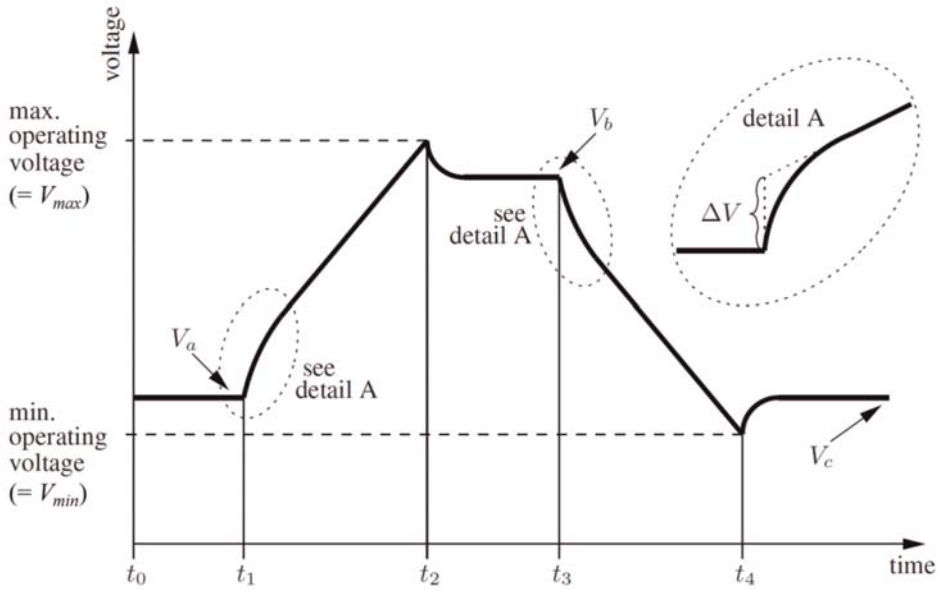
Figure 2

Example of voltage curve for the capacitor UUT measurement



$\Delta V(t_1)$ is the absolute difference of voltages between V_a and the intercept value of the straight-line approximation at the time of t_1.

$\Delta V(t_3)$ is the absolute difference of voltages between V_b and the intercept value of the straight-line approximation at the time of t_3.

$\Delta V(t_2)$ is the absolute difference of voltages between V_{max} and V_b.

$\Delta V(t_4)$ is the absolute difference of voltages between V_{min} and V_c.

6.4. Post-processing of measurement data of the capacitor UUT

6.4.1 Calculation of internal resistance and capacitance

The measurement data obtained in accordance with point 6.3 shall be used to calculate the internal resistance (R) and capacitance (C) values in accordance with the following equations:

(a) The capacitance for charging and discharging shall be calculated as follows:

For charging:

$$C_{charge} = \frac{\sum_{t_1}^{t_2} \mathrm{I}_{meas} \Delta t}{V_b - V_a}$$

For discharging:

$$C_{discharge} = \frac{\sum_{t_3}^{t_4} I_{meas} \Delta t}{V_c - V_b}$$

▼**M3**

(b) The maximum current for charging and discharging shall be calculated as follows:

For charging:

$$I_{max,charging} = \frac{\sum_{t_1}^{t_2} I_{meas} \Delta t}{t_2 - t_1}$$

For discharging:

$$I_{max,discharging} = \frac{\sum_{t_3}^{t_4} I_{meas} \Delta t}{t_4 - t_3}$$

(c) The internal resistance for charging and discharging shall be calculated as follows:

For charging:

$$R_{charge} = \frac{\Delta V(t_1) - \Delta V(t_2)}{2 I_{max,\ charging}}$$

For discharging:

$$R_{discharge} = \frac{\Delta V(t_3) - \Delta V(t_4)}{2 I_{max,\ discharging}}$$

(d) For the model, only a single capacitance and resistance are needed and these shall be calculated as follows:

Capacitance C:

$$C = \frac{C_{charge} - C_{discharge}}{2}$$

Resistance R:

$$R = \frac{R_{charge} - R_{discharge}}{2}$$

(e) The maximum voltage shall be defined as the recorded value of V_b and the minimum voltage shall be defined as the recorded value of V_c as defined in accordance with subpoint (f) of point 6.3.

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Appendix 1

MODEL OF A CERTIFICATE OF A COMPONENT, SEPARATE TECHNICAL UNIT OR SYSTEM

Maximum format: A4 (210 × 297 mm)

CERTIFICATE ON CO_2 EMISSIONS AND FUEL CONSUMPTION RELATED PROPERTIES OF AN ELECTRIC MACHINE SYSTEM / IEPC / IHPC Type 1 / BATTERY SYSTEM/ CAPACITOR SYSTEM

Administration stamp

Communication concerning:

— granting [(1)]

— extension[(1)]

— refusal[(1)]

— withdrawal[(1)]

of a certificate on CO_2 emission and fuel consumption related properties of an electric machine system / IEPC / IHPC Type 1 / battery system / capacitor system in accordance with Commission Regulation (EU) 2017/2400.

Commission Regulation (EU) 2017/2400 as last amended by …………….

Certification number:

Hash:

Reason for extension:

▼**M3**

SECTION I

0.1. Make (trade name of manufacturer):

0.2. Type:

0.3. Means of identification of type

0.3.1. Location of the certification marking:

0.3.2. Method of affixing certification marking:

0.5. Name and address of manufacturer:

0.6. Name(s) and address(es) of assembly plant(s):

0.7. Name and address of the manufacturer's representative (if any)

SECTION II

1. Additional information (where applicable): see Addendum

2. Approval authority responsible for carrying out the tests:

3. Date of test report:

4. Number of test report:

5. Remarks (if any): see Addendum

6. Place:

7. Date:

8. Signature:

Attachments:

Information package. Test report.

▼M3

Appendix 2

Information Document for an electric machine system

Information document no.:	Issue:
	Date of issue:
	Date of Amendment:

pursuant to …

Electric machine system type / family (if applicable):

…

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0. GENERAL

0.1. Name and address of manufacturer

0.2. Make (trade name of manufacturer):

0.3. Electric machine system type:

0.4. Electric machine system family:

0.5. Electric machine system type as separate technical unit / Electric machine system family as separate technical unit

0.6. Commercial name(s) (if available):

0.7. Means of identification of model, if marked on the Electric machine system:

0.8. In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9. Name(s) and address(es) of assembly plant(s):

0.10. Name and address of the manufacturer's representative:

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PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) ELECTRIC MACHINE SYSTEM AND THE ELECTRIC MACHINE SYSTEM TYPES WITHIN AN ELECTRIC MACHINE SYSTEM FAMILY

	Parent EMS or EMS type	Family members		
		#1	#2	#3
1. General				
1.1. Test voltage(s): V				
1.2. Basic motor rotational speed: 1/min				
1.3. Motor output shaft maximum speed: 1/min				
1.4. (or by default) reducer/gearbox outlet shaft speed: 1/min				
1.5. Maximum power speed: 1/min				
1.6. Maximum power: kW				
1.7. Maximum torque speed: 1/min				
1.8. Maximum torque: Nm				
1.9. Maximum 30 minutes power: kW				
2. Electric machine				
2.1. Working principle				
2.1.1. Direct current (DC)/alternating current (AC):				
2.1.2. Number of phases:				
2.1.3. Excitation / separate / series / compound:				
2.1.4. Synchron / asynchron:				
2.1.5. Rotor coiled / with permanent magnets / with housing:				
2.1.6. Number of poles of the motor:				
2.2. Rotational inertia: kgm^2				
3. Power controller				
3.1. Make:				
3.2. Type:				
3.3. Working principle:				
3.4. Control principle: vectorial / open loop / closed / other (t.b.s.):				
3.5. Maximum effective current supplied to the motor: A				

▼**M3**

3.6. For maximum duration of: s

3.7. DC voltage range used (from / to): V

3.8. DC/DC converter is part of the electric machine system in accordance with paragraph 4.1 of this Annex (yes/no):

4. Cooling system

4.1. Motor (liquid / air / other t.b.s.):

4.2. Controller (liquid / air / other t.b.s.):

4.3. Description of the system:

4.4. Principle drawing(s):

4.5. Temperature boundary limits (min/max): K

4.6. At reference position:

4.7. Flow rates (min/max): ltr/min

5. Documented values from component testing

5.1. Efficiency figures for CoP ([1]):

5.2. Cooling system (declaration for each cooling circuit):

5.2.1. maximum coolant mass flow or volume flow or maximum inlet pressure:

5.2.2. maximum coolant temperatures:

5.2.3. maximum available cooling power:

5.2.4. Recorded average values for each test run

5.2.4.1. coolant volume flow or mass flow:

5.2.4.2. coolant temperature at the inlet of the cooling circuit:

5.2.4.3. coolant temperature at the inlet and outlet of the test bed heat exchanger on the side of the EMS:

([1]) determined in accordance with points 4.3.5 and 4.3.6 of this Annex

▼M3

LIST OF ATTACHMENTS

No.:	Description:	Date of issue:
1	Information on EMS test conditions …	
2	…	

▼**M3**

Attachment 1 to Electric machine system information document

Information on test conditions (if applicable)

1.1 …

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Appendix 3

Information Document for an IEPC

Information document no.:

Issue:

Date of issue:

Date of Amendment:

pursuant to …

IEPC type / family (if applicable):

…

▼**M3**

0. GENERAL

0.1. Name and address of manufacturer

0.2. Make (trade name of manufacturer):

0.3. IEPC type:

0.4. IEPC family:

0.5. IEPC type as separate technical unit / IEPC family as separate technical unit

0.6. Commercial name(s) (if available):

0.7. Means of identification of model, if marked on the IEPC:

0.8. In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9. Name(s) and address(es) of assembly plant(s):

0.10. Name and address of the manufacturer's representative:

▼M3

PART 1

ESSENTIAL CHARACTERISTICS OF THE (PARENT) IEPC AND THE IEPC TYPES WITHIN AN IEPC FAMILY

	Parent IEPC or IEPC type	Family members		
		#1	#2	#3

1. General

1.1. Test voltage(s): V

1.2. Basic motor rotational speed: 1/min

1.3. Motor output shaft maximum speed: 1/min

1.4. (or by default) reducer/gearbox outlet shaft speed: 1/min

1.5. Maximum power speed: 1/min

1.6. Maximum power: kW

1.7. Maximum torque speed: 1/min

1.8. Maximum torque: Nm

1.9. Maximum 30 minutes power: kW

1.10. Number of electric machines:

2. Electric machine (for each electric machine):

2.1. Electric machine ID:

2.2. Working principle

2.2.1. Direct current (DC)/alternating current (AC):

2.2.2. Number of phases:

2.2.3. Excitation / separate / series / compound:

2.2.4. Synchron / asynchron:

2.2.5. Rotor coiled / with permanent magnets / with housing:

2.2.6. Number of poles of the motor:

2.3. Rotational inertia: kgm^2

3. Power controller (for each power controller):

3.1. Corresponding electric machine ID:

3.2. Make:

3.3. Type:

3.4. Working principle:

▼M3

3.5. Control principle: vectorial / open loop / closed / other (t.b.s.):

3.6. Maximum effective current supplied to the motor: A

3.7. For maximum duration of: s

3.8. DC voltage range used (from / to): V

3.9. DC/DC converter is part of the electric machine system in accordance with paragraph 4.1 of this Annex (yes/no):

4. Cooling system

4.1. Motor (liquid / air / other t.b.s.):

4.2. Controller (liquid / air / other t.b.s.):

4.3. Description of the system:

4.4. Principle drawing(s):

4.5. Temperature boundary limits (min/max): K

4.6. At reference position:

4.7. Flow rates (min/max): g/min or ltr/min

5. Gearbox

5.1. Gear ratio, gearscheme and powerflow:

5.2. Center distance for countershaft transmissions:

5.3. Type of bearings at corresponding positions (if fitted):

5.4. Type of shift elements (tooth clutches, including synchronisers or friction clutches) at corresponding positions (where fitted):

5.5. Total number of forward gears:

5.6. Number of tooth shift clutches:

5.7. Number of synchronisers:

5.8. Number of friction clutch plates (except for single dry clutch with 1 or 2 plates):

5.9. Outer diameter of friction clutch plates (except for single dry clutch with 1 or 2 plates):

5.10. Surface roughness of the teeth (incl. drawings):

5.11. Number of dynamic shaft seals:

5.12. Oil flow for lubrication and cooling per transmission input shaft revolution

5.13. Oil viscosity at 100 C (± 10 %):

5.14. System pressure for hydraulically controlled gearboxes:

▼M3

5.15. Specified oil level in reference to central axis and in accordance with the drawing specification (based on average value between lower and upper tolerance) in static or running condition. The oil level is considered as equal if all rotating transmission parts (except for the oil pump and the drive thereof) are located above the specified oil level:

5.16. Specified oil level (± 1mm):

5.17. Gear ratios [-] and maximum input torque [Nm], maximum input power (kW) and maximum input speed [rpm] (for each forward gear):

6. Differential

6.1. Gear ratio:

6.2. Principle technical specifications:

6.3. Principle drawings:

6.4. Oil volume:

6.5. Oil level:

6.6. Oil specification:

6.7. Bearing type (type, quantity, inner diameter, outer diameter, width and drawing):

6.8. Seal type (main diameter, lip quantity):

6.9. Wheel ends (drawing):

6.9.1. Bearing type (type, quantity, inner diameter, outer diameter, width and drawing):

6.9.2. Seal type (main diameter, lip quantity):

6.9.3. Grease type:

6.10. Number of planetary / spur gears for differential:

6.11. Smallest width of planetary/ spur gears for differential:

7. Documented values from component testing

7.1. Efficiency figures for CoP (*):

7.2. Cooling system (declaration for each cooling circuit):

7.2.1. maximum coolant mass flow or volume flow or maximum inlet pressure:

7.2.2. maximum coolant temperatures:

7.2.3. maximum available cooling power:

7.2.4. Recorded average values for each test run

7.2.4.1. coolant volume flow or mass flow:

7.2.4.2. coolant temperature at the inlet of the cooling circuit:

7.2.4.3. coolant temperature at the inlet and outlet of the test bed heat exchanger on the side of the IEPC:

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LIST OF ATTACHMENTS

No.:	**Description:**	**Date of issue:**
1	Information on IEPC test conditions …	
2	…	

▼**M3**

Attachment 1 to IEPC information document

8. Information on test conditions (if applicable)

8.1. Maximum tested input speed [rpm]

8.2. Maximum tested input torque [Nm]

▼**M3**

Appendix 4

Information Document for an IHPC Type 1

For IHPCs Type 1 the information document shall consist of the applicable parts of the information document for electric machine systems in accordance with Appendix 2 of this Annex and of the information document for transmissions in accordance with Appendix 2 of Annex VI.

▼M3

Appendix 5

Information Document for a battery system or a representative battery subsystem type

Information document no.:

Issue:

Date of issue:

Date of Amendment:

pursuant to …

Battery system or representative battery subsystem type:

…

▼**M3**

0. GENERAL

0.1. Name and address of manufacturer

0.2. Make (trade name of manufacturer):

0.3. Battery system type:

0.4. -

0.5. Battery system type as separate technical unit

0.6. Commercial name(s) (if available):

0.7. Means of identification of model, if marked on the Battery system:

0.8. In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9. Name(s) and address(es) of assembly plant(s):

0.10. Name and address of the manufacturer's representative:

▼**M3**

PART 1

ESSENTIAL CHARACTERISTICS OF THE BATTERY SYSTEM OR THE REPRESENTATIVE BATTERY SUBSYSTEM TYPE

Battery (sub)system type

1. General

1.1. Complete system or representative subsystem:

1.2. HPBS / HEBS:

1.3. Principle technical specifications:

1.4. Cell chemistry:

1.5. Number of cells in series:

1.6. Number of cells in parallel:

1.7. Representative junction box with fuses and breakers included in tested system (yes/no):

1.8. Representative serial connectors included in the tested system (yes/no):

2. Conditioning system

2.1. Liquid / air / other t.b.s.:

2.2. Description of the system:

2.3. Principle drawing(s):

2.4. Temperature boundary limits (min/max): K

2.5. At reference position:

2.6. Flow rates (min/max): ltr/min

3. Documented values from component testing

3.1. Round trip efficiency for CoP (**):

3.2. Maximum discharge current for CoP:

3.3. Maximum charge current for CoP:

3.4. Testing temperature (target operating temperature declared):

3.5. Conditioning system (indicate for each test run performed)

3.5.1. Cooling or heating required:

3.5.2. Maximum available cooling or heating power:

▼**M3**

LIST OF ATTACHMENTS

No.:	**Description:**	**Date of issue:**
1	Information on Battery system test conditions …	
2	…	

▼**M3**

Attachment 1 to Battery system information document

Information on test conditions (if applicable)

1.1 …

▼**M3**

Appendix 6

Information Document for a capacitor system or a representative capacitor subsystem type

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Information document no.: Issue:

Date of issue:

Date of Amendment:

pursuant to …

Capacitor system or representative capacitor subsystem type:

…

▼M3

0. GENERAL

0.1. Name and address of manufacturer

0.2. Make (trade name of manufacturer):

0.3. Capacitor system type:

0.4. Capacitor system family:

0.5. Capacitor system type as separate technical unit / Capacitor system family as separate technical unit

0.6. Commercial name(s) (if available):

0.7. Means of identification of model, if marked on the Capacitor system:

0.8. In the case of components and separate technical units, location and method of affixing of the EC approval mark:

0.9. Name(s) and address(es) of assembly plant(s):

0.10. Name and address of the manufacturer's representative:

▼M3

PART 1

ESSENTIAL CHARACTERISTICS OF THE CAPACITOR SYSTEM OR THE REPRESENTATIVE CAPACITOR SUBSYSTEM TYPE

Capacitor (sub)system type

1. General

1.1. Complete system or representative subsystem:

1.2. Principle technical specifications:

1.3. Cell technology and specification:

1.4. Number of cells in series:

1.5. Number of cells in parallel:

1.6. Representative junction box with fuses and breakers included in tested system (yes/no):

1.7. Representative serial connectors included in the tested system (yes/no):

2. Conditioning system

2.1. Liquid / air / other t.b.s.:

2.2. Description of the system:

2.3. Principle drawing(s):

2.4. Temperature boundary limits (min/max): K

2.5. At reference position:

2.6. Flow rates (min/max): ltr/min

3. Documented values from component testing

3.1. Testing temperature (target operating temperature declared):

3.2. Conditioning system (indicate for each test run performed)

3.2.1. Cooling or heating required:

3.2.2. Maximum available cooling or heating power:

▼**M3**

LIST OF ATTACHMENTS

No.:	Description:	Date of issue:
1	Information on Capacitor system test conditions …	
2	…	

▼**M3**

Attachment 1 to Capacitor system information document

Information on test conditions (if applicable)

1.1 …

▼**M3**

Appendix 7

(reserved)

▼**M3**

Appendix 8

Standard values for electric machine system

The following steps shall be performed to generate the input data for the electric machine system based on standard values:

— Step 1: UN Regulation No. 85 shall be applied for this Appendix unless stated otherwise.

— Step 2: The maximum torque values as a function of the rotational speed shall be determined from the data generated in accordance with paragraph 5.3.1.4 of UN Regulation No. 85. The data shall be extended in accordance with point 4.3.2 of this Annex.

— Step 3: The minimum torque values as a function of the rotational speed shall be determined by multiplying the torque values from Step 2 above by minus one.

— Step 4: The maximum 30 minutes continuous torque and the corresponding rotational speed shall be determined from the data generated in accordance with paragraph 5.3.2.3 of UN Regulation No. 85 as average values over the 30 minutes period. In case no value for the maximum 30 minutes continuous torque in accordance with Regulation No. 85 can be determined or the value determined is 0 Nm, the applicable input data shall be set to 0 Nm and the corresponding rotational speed shall be set to the rated speed determined from the data generated in accordance with Step 2 above.

— Step 5: The overload characteristics shall be determined from the data generated in accordance with Step 2 above. The overload torque and the corresponding rotational speed shall be calculated as average values over the speed range where the power is equal or greater than 90 % of the maximum power. The overload duration t_{0_maxP} shall be defined by the whole duration of the test run performed in accordance with Step 2 above multiplied by a factor of 0,25.

— Step 6: The electric power consumption map shall be determined in accordance with the following provisions:

(a) A normalised power loss map shall be calculated as a function of normalised speed and torque values in accordance with the following equation:

$$P_{loss,norm}(T_{norm,i}, \omega_{norm,j}) = \sum_{m,n=0}^{3} k_{mn} |T_{norm,i}|^m |\omega_{norm,j}|^n$$

where:

$P_{loss,norm}$ = normalised loss power [–]

$T_{norm,i}$ = normalised torque for all gridpoints defined in accordance with subpoint (b)(ii) below [–]

$\omega_{norm,j}$ = normalised speed for all gridpoints defined in accordance with subpoint (b)(i) below [–]

k = loss coefficient [–]

m = index regarding torque dependent losses running from 0 to 3 [–]

n = index regarding speed dependent losses running from 0 to 3 [–]

▼M3

(b) The normalised speed and torque values to be used for the equation in subpoint (a) above defining the grid points of the normalised loss map shall be:

(i) normalised speed: 0,02, 0,20, 0,40, 0,60, 0,80, 1,00, 1,20, 1,40, 1,60, 1,80, 2,00, 2,20, 2,40, 2,60, 2,80, 3,00, 3,20, 3,40, 3,60, 3,80, 4,00 Where the highest rotational speed determined from the data generated in accordance with Step 2 above is located higher than a normalised speed value of 4,00, additional values of normalised speed with an increment of 0,2 shall be added to the existing list in order to cover the required speed range.

(ii) normalised torque: – 1,00, – 0,95, – 0,90, – 0,85, – 0,80, – 0,75, – 0,70, – 0,65, – 0,60, – 0,55, – 0,50, – 0,45, – 0,40, – 0,35, – 0,30, – 0,25, – 0,20, – 0,15, – 0,10, – 0,05, – 0,01, 0,01, 0,05, 0,10, 0,15, 0,20, 0,25, 0,30, 0,35, 0,40, 0,45, 0,50, 0,55, 0,60, 0,65, 0,70, 0,75, 0,80, 0,85, 0,90, 0,95, 1,00

(c) The loss coefficient k to be used for the equation in subpoint (a) above shall be defined depending on the indices m and n in accordance with the following tables:

(i) In the case of an electric machine of the type PSM:

		n			
		0	**1**	**2**	**3**
m	**3**	0	0	0	0
	2	0,018	0,001	0,03	0
	1	0,0067	0	0	0
	0	0	0,005	0,0025	0,003

(ii) In the case of an electric machine of all other types except PSM:

		n			
		0	**1**	**2**	**3**
m	**3**	0	0	0	0
	2	0,1	0,03	0,03	0
	1	0,01	0	0,001	0
	0	0,003	0	0,001	0,001

(d) From the normalised power loss map determined in accordance with subpoints (a) to (c) above, the efficiency shall be calculated in accordance with the following provisions:

(i) The grid points for the normalised speed shall be: 0,02, 0,20, 0,40, 0,60, 0,80, 1,00, 1,20, 1,40, 1,60, 1,80, 2,00, 2,20, 2,40, 2,60, 2,80, 3,00, 3,20, 3,40, 3,60, 3,80, 4,00

Where the highest rotational speed determined from the data generated in accordance with Step 2 above is located higher than a normalised speed value of 4,00, additional values of normalised speed with an increment of 0,2 shall be added to the existing list in order to cover the required speed range.

▼**M3**

(ii) The grid points for the normalised torque shall be: – 1,00, – 0,95, – 0,90, – 0,85, – 0,80, – 0,75, – 0,70, – 0,65, – 0,60, – 0,55, – 0,50, – 0,45, – 0,40, – 0,35, – 0,30, – 0,25, – 0,20, – 0,15, – 0,10, – 0,05, – 0,01, 0,01, 0,05, 0,10, 0,15, 0,20, 0,25, 0,30, 0,35, 0,40, 0,45, 0,50, 0,55, 0,60, 0,65, 0,70, 0,75, 0,80, 0,85, 0,90, 0,95, 1,00

(iii) For each gridpoint defined in accordance with subpoints (d)(i) and (d)(ii) above the efficiency η shall be calculated in accordance with the following equations:

— Where the actual value of the grid point for the normalised torque is smaller than zero:

$$\eta(T_{norm,i}, \omega_{norm,j}) = \frac{T_{norm,i} \times \omega_{norm,j} + P_{loss,norm}(T_{norm,i}, \omega_{norm,j})}{T_{norm,i} \times \omega_{norm,j}} \times 0{,}96$$

Where the resulting value for η is smaller than zero, it shall be set to zero.

— Where the actual value of the grid point for the normalised torque is larger than zero:

$$\eta(T_{norm,i}, \omega_{norm,j}) = \frac{T_{norm,i} \times \omega_{norm,j}}{T_{norm,i} \times \omega_{norm,j} + P_{loss,norm}(T_{norm,i}, \omega_{norm,j})} \times 0{,}96$$

where:

η = efficiency [–]

$T_{norm,i}$ = normalised torque for all gridpoints defined in accordance with subpoint (d)(ii) above [–]

$\omega_{norm,j}$ = normalised speed for all gridpoints defined in accordance with subpoint (d)(i) above [–]

$P_{loss,norm}$ = normalised loss power determined in accordance with subpoints (a) to (c) above [–]

(e) From the efficiency map determined in accordance with subpoint (d) above, the actual power loss map of the electric machine system shall be calculated in accordance with the following provisions:

(i) For each gridpoint of normalised speed defined in accordance with subpoint (d)(i) above the actual speed values n_j shall be calculated in accordance with the following equation:

$$n_j = \omega_{norm,j} \times n_{rated}$$

where:

n_j = actual speed [1/min]

$\omega_{norm,j}$ = normalised speed for all gridpoints defined in accordance with subpoint (d)(i) above [–]

n_{rated} = rated speed of the electric machine system determined from the data generated in accordance with Step 2 above [1/min]

▼**M3**

(ii) For each gridpoint of normalised torque defined in accordance with subpoint (d)(ii) above the actual torque values T_i shall be calculated in accordance with the following equation:

$$T_i = T_{norm,i} \times T_{max}$$

where:

T_i = actual torque [Nm]

$T_{norm,i}$ = normalised torque for all gridpoints defined in accordance with subpoint (d)(ii) above [–]

T_{max} = overall maximum torque of the electric machine system determined from the data generated in accordance with Step 2 above [Nm]

(iii) For each gridpoint defined in accordance with subpoints (e)(i) and (e)(ii) above the actual power loss shall be calculated in accordance with the following equation:

$$P_{loss}(T_i, n_j) = (1 - n(\frac{T_i}{T_{max}}, \frac{n_j}{n_{rated}})) \times |T_i| \times n_j \times \frac{2\pi}{60}$$

where:

P_{loss} = actual loss power [W]

T_i = actual torque [Nm]

n_j = actual speed [1/min]

η = efficiency dependent on normalised speed and torque determined in accordance with subpoint (d) above [–]

T_{max} = overall maximum torque of the electric machine system determined from the data generated in accordance with Step 2 above [Nm]

n_{rated} = rated speed of the electric machine system determined from the data generated in accordance with Step 2 above [1/min]

(iv) For each gridpoint defined in accordance with subpoints (e)(i) and (e)(ii) above the actual electric inverter power shall be calculated in accordance with the following equation:

$$P_{el}(T_i, n_j) = P_{loss}(T_i, n_j) + T_i \times n_j \times \frac{2\pi}{60}$$

where:

P_{el} = actual electric inverter power [W]

P_{loss} = actual loss power [W]

T_i = actual torque [Nm]

n_j = actual speed [1/min]

(f) The data of the actual electric power map determined in accordance with subpoint (e) above shall be extended in accordance with subpoints (1), (2), (4) and (5) of point 4.3.4 of this Annex.

▼M3

— Step 7: The drag curve shall be calculated based on the actual power loss map determined in accordance with subpoint (e) above in accordance with the following provisions:

(a) From the power loss values for the two gridpoints defined by the normalised torque $\frac{T_i}{T_{max}} = 0{,}01$, and values of 1,00 and 4,00 for normalised speed $\frac{n_j}{n_{rated}}$, the drag torque depending on actual speed and torque shall be calculated in accordance with the following equation:

$$T_{drag}\left(T_i | \frac{T_i}{T_{max}} = 0{,}01, n_j | \frac{n_j}{n_{rated}} = \{1{,}00; 4{,}00\}\right) = -P_{loss}\left(T_i | \frac{T_i}{T_{max}} = 0{,}01, n_j | \frac{n_j}{n_{rated}} = \{1{,}00; 4{,}00\}\right) \times \frac{60}{2\pi \times n_j}$$

where:

T_{drag} = actual drag torque [Nm]

T_i = actual torque [Nm]

T_{max} = overall maximum torque of the electric machine system determined from the data generated in accordance with Step 2 above [Nm]

n_j = actual speed [1/min]

n_{rated} = rated speed of the electric machine system determined from the data generated in accordance with Step 2 above [1/min]

P_{loss} = actual loss power [W]

(b) From the two values of drag torque determined in accordance with subpoint (a) above, a third value of drag torque at zero rotational speed shall be calculated by means of linear extrapolation.

(c) From the two values of drag torque determined in accordance with subpoint (a) above, a fourth value of drag torque at the maximum normalised speed value defined in accordance with subpoint (b)(i) of Step 6 above shall be calculated by means of linear extrapolation.

— Step 8: The rotational inertia shall be determined by one of the following options:

(a) Option 1: Based on the actual rotational inertia defined by the geometric form and the density of the respective materials of the rotor of the electric machine. Data and methods from a CAD software tool may be used to derive the actual rotational inertia of the rotor of the electric machine. The detailed method for determining the rotational inertia shall be agreed with the type approval authority.

(b) Option 2: Based on the outer dimensions of the rotor of the electric machine. A hollow cylinder shall be defined to fit the dimensions of the rotor of the electric machine in a way that:

(i) The outer diameter of the cylinder matches the point of the rotor with the largest distance from the rotational axis of the rotor assessed along a straight line orthogonal to the rotational axis of the rotor.

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(ii) The inner diameter of the cylinder matches the point of the rotor with the smallest distance from the rotational axis of the rotor assessed along a straight line orthogonal to the rotational axis of the rotor.

(iii) The length of the cylinder matches the distance between the two points located furthest from each other assessed along a straight line parallel to the rotational axis of the rotor.

For the hollow cylinder defined in accordance with subpoints (i) to (iii) above the rotational inertia shall be calculated with a material density of 7 850 kg/m^3.

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Appendix 9

Standard values for IEPC

In order to allow using the provisions defined in this Appendix to generate input data for IEPC based fully or partially on standard values, the following conditions shall be fulfilled.

Where more than one electric machine system is part of the IEPC, all electric machines shall have the exact same specifications. Where more than one electric machine system is part of the IEPC, all electric machines shall be connected to the torque path of the IEPC at the same reference position (i.e. either upstream of gearbox or downstream of gearbox) where all electric machines shall be run at the same rotational speed at this reference position and their individual torque (power) shall be added by any kind of summation gearbox.

(1) One of the following options shall be used to generate the input data for IEPC, based fully or partially on standard values:

— Option 1: only standard values for all components part of the IEPC

(a) The standard values for the electric machine system as part of the IEPC shall be determined in accordance with Appendix 8. Where multiple electric machines are part of the IEPC, the standard values in accordance with Appendix 8 shall be determined for a single electric machine and all figures for torque and power (mechanical and electrical) shall be multiplied by the total number of electric machines being part of the IEPC. The resulting values from this multiplication shall be used for all further steps in this Appendix.

The value for rotational inertia determined in accordance with Step 8 of Appendix 8 of this Annex shall be multiplied by the total number of electric machines being part of the IEPC.

(b) Where a gearbox is included in the IEPC, the standard values for the IEPC shall be determined for each forward gear separately for the electric power consumption map, and only for the gear with the gear ratio closest to 1 for all other input data in accordance with the following procedure:

(i) The standard values for losses in the gearbox shall be determined in accordance with point (2) of this Appendix.

(ii) For step number (i) above the rotational speed and torque points defined at the shaft of the electric machine system determined in accordance with subpoint (a) above shall be used as rotational speed and torque values at the input shaft of the gearbox.

(iii) In order to generate the required input data for IEPC in accordance with Appendix 15 referring to the output shaft of the gearbox, all torque values referring to the output shaft of the electric machine determined in accordance with subpoint (a) above shall be converted to the output shaft of the gearbox by the following equation:

$$T_{i,GBX} = (T_{i,EM} - T_{i,l,in}\ (n_{j,EM},\ T_{i,EM},\ gear)) \times i_{gear}$$

where:

$T_{i,GBX}$ = torque at output shaft of gearbox

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$T_{i,EM}$ = torque at output shaft of electric machine system

$T_{i,l,in}$ = torque loss for each shiftable forward gear related to the input shaft of the gearbox parts of the IEPC determined in accordance with point (b)(i) above

$n_{j,EM}$ = Speed at the output shaft of electric machine system at which $T_{i,EM}$ was measured [rpm]

i_{gear} = gear ratio of a specific gear [-]

(where gear = 1, …, highest gear number)

(iv) In order to generate the required input data for IEPC in accordance with Appendix 15 referring to the output shaft of the gearbox, all speed values referring to the output shaft of the electric machine determined in accordance with subpoint (a) above shall be converted to the output shaft of the gearbox by the following equation:

$$n_{j,GBX} = n_{j,EM} / i_{gear}$$

where:

$n_{j,EM}$ = Speed at the output shaft of electric machine [rpm]

i_{gear} = gear ratio of a specific gear [-]

(where gear = 1, …, highest gear number)

(c) Where a differential is included in the IEPC, the standard values for the differential shall be determined for each forward gear separately for the electric power consumption map and only for the for the gear with the gear ratio closest to 1 for all other input data in accordance with the following steps:

(i) The standard values for losses in the differential shall be determined in accordance with point (3) of this Appendix.

(ii) The torque points defined at the output shaft of the gearbox being part of the IEPC determined in accordance with subpoint (b) above shall be used as torque values at the input of the differential. Where no gearbox is included in the IEPC, the torque points defined at the output shaft of the electric machine system determined in accordance with subpoint (a) above shall be used as torque values at the input of the differential for step number (i) above.

(iii) In order to generate the required input data for IEPC in accordance with Appendix 15 referring to the output of the differential, all torque values referring to the output shaft of either the gearbox (where a gearbox is included in the IEPC) determined in accordance with step number (iii) of subpoint (b) above or the electric machine system (in the case that no gearbox is included in the IEPC) determined in accordance with subpoint (a) above shall be converted to the output of the differential by the following equation:

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$$T_{i,diff,out} = (T_{i,diff,in} - T_{i,diff\_l,in} (T_{i,diff,in})) \times i_{diff}$$

where:

$T_{i,diff,out}$ = torque at output of differential

$T_{i,diff,in}$ = torque at input of differential

$T_{i,diff\_l,in}$ = torque loss related to the input of the differential dependent on the input torque determined in accordance with point (c)(i) above

i_{diff} = differential gear ratio [-]

(iv) In order to generate the required input data for IEPC in accordance with Appendix 15 referring to the output of the differential, all speed values referring to the output shaft of either the gearbox (where a gearbox is included in the IEPC) determined in accordance with step number (iv) of subpoint (b) above or the electric machine system (where no gearbox is included in the IEPC) determined in accordance with subpoint (a) above shall be converted to the output of the differential by the following equation:

$$n_{j,diff,out} = n_{j,diff,in} / i_{diff}$$

where:

$n_{j,diff,in}$ = speed at input of differential [rpm]

i_{diff} = differential gear ratio [-]

— Option 2: measurement of electric machine system as part of the IEPC and standard values for other components of IEPC

(a) The measured component data for the electric machine system as part of the IEPC shall be determined in accordance with point 4 of this Annex. In the case of multiple electric machines being part of the IEPC, the component data shall be determined for a single electric machine and all figures for torque and power (mechanical and electrical) shall be multiplied by the total number of electric machines being part of the IEPC. The resulting values from this multiplication shall be used for all further steps in this Appendix.

The value for rotational inertia determined in accordance with point 8 of Appendix 8 of this Annex shall be multiplied by the total number of electric machines being part of the IEPC.

(b) Where a gearbox is included in the IEPC, the standard values for the IEPC shall be determined for each forward gear separately for the electric power consumption map and only for the gear with the gear ratio closest to 1 for all other input data in accordance with the provisions of Option 1(b) above. In this context all references in Option 1(b) to subpoint (a) shall be understood as references to subpoint (a) of Option 2.

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(c) Where a differential is included in the IEPC, the standard values for the differential shall be determined for each forward gear separately for the electric power consumption map and only for the gear with the gear ratio closest to 1 for all other input data in accordance with Option 1(c) above. In this context all references in Option 1(c) to subpoint (b) shall be understood as references to subpoint (b) of Option 2.

(2) IEPC internal component gearbox

The torque loss $T_{gbx,l,in}$ for each shiftable forward gear related to the input shaft of the gearbox parts of the IEPC shall be calculated in accordance with the following provisions:

(a) $T_{gbx,l,in} (n_{in}, T_{in}, gear) = T_{d0} + T_{d1000} \times n_{in} / 1000 \text{ rpm} + f_{T,gear} \times T_{in}$

where:

$T_{gbx,l,in}$ = Torque loss related to the input shaft [Nm]

T_{dx} = Drag torque at x rpm [Nm]

n_{in} = Speed at the input shaft [rpm]

$f_{T,gear}$ = Gear dependent torque loss coefficient [-];

determined acc. to subpoints (b)-(f) below

T_{in} = Torque at the input shaft [Nm]

gear = 1, …, highest gear number [-]

(b) The values of the equation shall be determined for all transmission gears located downstream of the EM output shaft.

(c) Where a differential is included in the IEPC, the values of the equation shall be determined for all transmission gears located downstream of the EM output shaft and upstream of, but excluding the gear mesh with the differential input gear. The gear mesh with the differential input gear can be an external-external gear mesh (either spur or bevel) or a single planetary gearset.

(d) In the case of wheel hub motors, the values of the equation shall be determined for all transmission gears located downstream of the EM output shaft and upstream of the wheel hub.

(e) The value for f_T shall be determined in accordance with paragraph 3.1.1 of Annex VI.

(f) The value for f_T shall be 0,007 for a direct gear.

(g) The values for T_{d0} and T_{d1000} shall be 0,0075 × $T_{max,in}$ for gearboxes with more than 2 friction shift clutches.

(h) The values for T_{d0} and T_{d1000} shall be 0,0025 × $T_{max,in}$ for all other gearboxes.

(i) $T_{max,in}$ shall be the overall maximum value of all individual maximum allowed input torque for each forward gear of the gearbox in [Nm].

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(3) IEPC internal component differential

The torque loss $T_{diff,l,in}$ related to the input of the differential parts of the IEPC shall be calculated in accordance with the following provisions:

(a) $T_{diff,l,in}(T_{in}) = \eta_{diff} \times T_{diff,d0} / i_{diff} + (1- \eta_{diff}) \times T_{in}$

where:

$T_{diff,l,in}$ = Torque loss related to the input of the differential [Nm]

$T_{diff,d0}$ = Drag torque [Nm]

determined acc. to subpoints (e)-(f) below

η_{diff} = Torque dependent efficiency [-];

determined acc. to subpoints (b)-(d) below

T_{in} = Torque at the input of the differential [Nm]

i_{diff} = differential gear ratio [-]

(b) The values of the equation shall be determined for all gear meshes of the differential including the gear mesh with the differential input gear.

(c) The value for η_{diff} shall be determined in accordance with paragraph 3.1.1 of Annex VI, where in the respective equations η_m shall be set to 0,98 in the case of a bevel gear mesh.

(d) The losses in the differential internal gears are shall be ignored for the calculations performed in accordance with subpoints (b)-(c) above.

(e) In the case of a differential that includes a bevel gear mesh at the differential crown gear, the value for $T_{diff,d0}$ shall be determined based on the following equation: $T_{diff,d0}$ = 25 Nm + 15 Nm × i_{diff}

(f) In the case of a differential that includes a spur gear mesh or single planetary gearset at the differential input gear, the value for $T_{diff,d0}$ shall be determined based on the following equation: $T_{diff,d0}$ = 25 Nm + 5 Nm × i_{diff}

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Appendix 10

Standard values for REESS

(1) Battery system or representative battery subsystem

The following steps shall be performed to generate the input data for the battery system or representative battery subsystem based on standard values:

(a) The battery type shall be determined based on the numerical ratio between maximum current in A (as indicated in accordance with point 1.4.4 of Annex 6 – Appendix 2 of UN Regulation No. 100 (***) and capacity in Ah (as indicated in accordance with point 1.4.3 of Annex 6 – Appendix 2 of UN Regulation No. 100). The battery type shall be 'high-energy battery system (HEBS)' where this ratio is lower than 10 and shall be 'high-power battery system (HPBS)' where this ratio is equal to or higher than 10.

(b) The rated capacity shall be the value in Ah as indicated in accordance with paragraph 1.4.3 of Annex 6 – Appendix 2 of UN Regulation No. 100.

(c) The OCV as a function of SOC shall be determined based on the nominal voltage in V, V_{nom}, as indicated in accordance with paragraph 1.4.1 of Annex 6 – Appendix 2 of UN Regulation No. 100. The values of OCV for different levels of SOC shall be calculated in accordance with the following table:

SOC [%]	OCV [V]
0	0,88 × V_{nom}
10	0,94 × V_{nom}
50	1,00 × V_{nom}
90	1,06 × V_{nom}
100	1,12 × V_{nom}

(d) The DCIR shall be determined in accordance with the following provisions:

(i) For HPBS in accordance with subpoint (a) above the DCIR shall be calculated by dividing the specific resistance of 25 [mOhm × Ah] by the rated capacity in Ah as defined in accordance with subpoint (b) above.

(ii) For HEBS in accordance with subpoint (a) above the DCIR shall be calculated by dividing the specific resistance of 140 [mOhm × Ah] by the rated capacity in Ah as defined in accordance with subpoint (b) above.

(e) The values for maximum charging and maximum discharging current shall be determined in accordance with the following provisions:

(i) For HPBS in accordance with subpoint (a) above the values for both, maximum charging and maximum discharging current, shall be set to the respective current in A corresponding to 10C.

(ii) For HEBS in accordance with subpoint (a) above the values for both, maximum charging and maximum discharging current, shall be set to the respective current in A corresponding to 1C.

▼**M3**

Absolute values for both, maximum charging and maximum discharging current, shall be used as final values.

(2) Capacitor system or representative capacitor subsystem

The following steps shall be performed to generate the input data for the capacitor system or representative capacitor subsystem based on standard values:

(a) The capacitance shall be the rated capacitance as indicated in the datasheet of the capacitor system or representative capacitor subsystem. The actual capacitance of the capacitor system or representative capacitor subsystem may be determined by scaling up the rated capacitance of a single capacitor cell in accordance with the arrangement (i.e. series and/or parallel) of the single cells in the capacitor system or representative capacitor subsystem.

(b) The maximum voltage, $V_{max,Cap}$, shall be the rated voltage as indicated in the datasheet of the capacitor system or representative capacitor subsystem. The actual maximum voltage of the capacitor system or representative capacitor subsystem may be determined by scaling up the rated voltage of a single capacitor cell in accordance with the arrangement (i.e. series and/or parallel) of the single cells in the capacitor system or representative capacitor subsystem.

(c) The minimum voltage, $V_{min,Cap}$, shall be the value of $V_{max,Cap}$ determined in accordance with subpoint (b) above multiplied by 0,45.

(d) The internal resistance shall be determined in accordance with the following equation:

$$R_{I,Cap} = R_{I,ref} \times \frac{V_{max,Cap} - V_{min,Cap}}{0{,}55 \times V_{ref}} \times \frac{C_{ref}}{C_{Cap}}$$

where:

$R_{I,Cap}$	=	Internal resistance [Ohm]
$R_{I,ref}$	=	Reference for internal resistance with a numeric value of 0,015 [Ohm]
$V_{max,Cap}$	=	Maximum voltage as defined in accordance with subpoint (b) above [V]
$V_{min,Cap}$	=	Minimum voltage as defined in accordance with subpoint (c) above [V]
V_{ref}	=	Reference for maximum voltage with a numeric value of 2,7 [V]
C_{ref}	=	Reference for capacitance with a numeric value of 3 000 [F]
C_{Cap}	=	Capacitance as defined in accordance with subpoint (a) above [F]

(e) The values for both, maximum charging and maximum discharging current, shall be calculated by multiplying the value of the capacitance in F as defined in accordance with subpoint (a) above by a factor of 5,0 [A/F]. Absolute values for both, maximum charging and maximum discharging current, shall be used as final values.

▼**M3**

Appendix 11

(reserved)

▼**M3**

Appendix 12

Conformity of the certified CO_2 emissions and fuel consumption related properties

1. Electric machine systems or IEPCs

1.1 Every electric machine system or IEPC shall be so manufactured as to conform to the approved type with regard to the description as given in the certificate and its annexes. The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply with those set out in Article 31 of Regulation (EU) 2018/858.

1.2 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificates and information packages annexed thereto as set out in Appendices 2 and 3 of this Annex.

1.3 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be assessed in accordance with the specific conditions laid down in this paragraph.

1.4 The component manufacturer shall test annually at least the number of units indicated in Table 1 based on the total annual production number of electric machine systems or IEPCs produced by the component manufacturer. For the purpose of establishing the annual production numbers, only electric machine systems or IEPCs which fall under the requirements of this Regulation and for which no standard values were used shall be considered.

1.5 For total annual production volumes up to 4,000, the choice of the family for which the tests shall be performed shall be agreed between the component manufacturer and the approval authority.

1.6 For total annual production volumes above 4,000, the family with the highest production volume shall always be tested. The component manufacturer shall justify to the approval authority the number of tests which has been performed and the choice of the family. The remaining families for which the tests are to be performed shall be agreed between the manufacturer and the approval authority.

Table 1

Sample size conformity testing

Total annual production of either electric machine systems or IEPCs	Annual number of tests	Alternatively
0 – 1 000	n.a.	1 test every 3 years (*)
1 001 – 2 000	n.a.	1 test every 2 years (*)
2 001 – 4 000	1	n.a.
4 001 – 10 000	2	n.a.
10 001 – 20 000	3	n.a.
20 001 – 30 000	4	n.a.
30 001 – 40 000	5	n.a.
40 001 – 50 000	6	n.a.
> 50 000	7	n.a.

(*) The CoP test shall be performed in the first year

▼M3

1.7. For the purpose of the conformity of the certified CO_2 emissions and fuel consumption related properties testing the approval authority shall identify together with the component manufacturer the electric machine system or IEPC type(s) to be tested. The approval authority shall ensure that the selected electric machine system or IEPC type(s) is manufactured to the same standards as for serial production.

1.8 If the result of a test performed in accordance with point 1.9 is higher than the one specified in point 1.9.4, 3 additional units from the same family shall be tested. If any of them fails, Article 23 shall apply.

1.9 Production conformity testing of electric machine system or IEPC

1.9.1 Boundaries conditions

All boundary conditions as specified in this Annex for the certification testing shall apply unless stated otherwise in this paragraph.

The cooling power shall be within the limits as specified in this Annex for the certification testing.

The measurement shall only be performed for one of the voltage levels indicated in paragraph 4.1.3 of this Annex. The voltage level for testing shall be chosen by the component manufacturer.

The measurement equipment specifications defined in accordance with paragraph 3.1 of this Annex do not need to be fulfilled for CoP testing.

1.9.2 Test run

Two different setpoints shall be measured. After the measurement at the first setpoint is completed, the system may be cooled down in accordance with the component manufacturer's recommendations by running at a particular setpoint defined by the component manufacturer.

For setpoint 1 the test of overload characteristics shall be performed in accordance with paragraph 4.2.5 of this Annex.

For setpoint 2 the test of maximum 30 minutes continuous torque shall be performed in accordance with paragraph 4.2.4 of this Annex.

1.9.3 Post-processing of results

All values of mechanical and electrical power determined in accordance with paragraphs 4.2.5.3 and 4.2.4.3 shall be corrected for uncertainty deviation of CoP measurement equipment in accordance with the following provisions:

(a) The difference in measurement equipment uncertainty in % between component type approval and CoP testing in accordance with this Appendix shall be calculated for the measurement systems used for rotational speed, torque, current and voltage.

(b) The difference in uncertainty in % referred to in subpoint (a) above shall be calculated for both, the analyser reading and the maximum calibration value defined in accordance with paragraph 3.1 of this Annex.

▼**M3**

(c) The total difference in uncertainty for electrical power shall be calculated based on the following equation:

$$\Delta u_{P,el,CoP} = \sqrt{\Delta u^2_{U,max\ calib} + \Delta u^2_{U,value} + \Delta u^2_{I,max\ calib} + \Delta u^2_{I,value}}$$

where:

$\Delta u_{U,max\ calib}$	difference in uncertainty for maximum calibration value for voltage measurement [%]
$\Delta u_{U,value}$	difference in uncertainty for analyser reading for voltage measurement [%]
$\Delta u_{I,max\ calib}$	difference in uncertainty for maximum calibration value for current measurement [%]
$\Delta u_{I,value}$	difference in uncertainty for analyser reading for current measurement [%]

(d) The total difference in uncertainty for mechanical power shall be calculated based on the following equation:

$$\Delta u_{P,mech,CoP} = \sqrt{\Delta u^2_{T,max\ calib} + \Delta u^2_{T,value} + \Delta u^2_{n,max\ calib} + \Delta u^2_{n,value}}$$

where:

$\Delta u_{T,max\ calib}$	difference in uncertainty for maximum calibration value for torque measurement [%]
$\Delta u_{T,value}$	difference in uncertainty for analyser reading for torque measurement [%]
$\Delta u_{n,max\ calib}$	difference in uncertainty for maximum calibration value for rotational speed measurement [%]
$\Delta u_{n,value}$	difference in uncertainty for analyser reading for rotational speed measurement [%]

(e) All measured values of mechanical power shall be corrected based on the following equation:

$$P^*_{mech} = P_{mech,meas}\ (1 - \Delta u_{P,mech,CoP})$$

where:

$P_{mech,meas}$	measured value of mechanical power
$\Delta u_{P,mech,CoP}$	total difference in uncertainty for mechanical power in accordance with subpoint (d) above

(f) All measured values of electrical power shall be corrected based on the following equation:

$$P^*_{el} = P_{el,meas}\ (1 + \Delta u_{P,el,CoP})$$

where:

$P_{el,meas}$	measured value of electrical power
$\Delta u_{P,el,CoP}$	total difference in uncertainty for electrical power in accordance with subpoint (c) above

▼M3

1.9.4 Evaluation of results

From the values for each of the two different setpoints determined in accordance with paragraphs 1.9.2 and 1.9.3, the efficiency figures shall be determined dividing the corrected mechanical power P^{*}_{mech} by the corrected electrical power P^{*}_{el}.

The total efficiency during conformity of the certified CO_2 emissions and fuel consumption related properties testing $\eta_{A,CoP}$ shall be calculated by the arithmetic mean value of the two efficiency figures.

The conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when the difference between $\eta_{A,CoP}$ and $\eta_{A,TA}$ is lower than 3 % of the type approved efficiency $\eta_{A,TA}$. In the case of an IEPC with either a gearbox or a differential included, the limit for passing the CoP test is raised to 4 % instead of 3. In the case of an IEPC with both a gearbox and a differential included, the limit for passing the CoP test is raised to 5 % instead of 3.

The type approved efficiency $\eta_{A,TA}$ shall be calculated by the arithmetic mean value of the two efficiency figures determined in accordance with paragraphs 4.3.5 and 4.3.6 and documented in the information document during component certification.

2. IHPCs Type 1

2.1 Every IHPC shall be so manufactured as to conform to the approved type with regard to the description as given in the certificate and its annexes. The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply with those set out in Article 31 of Regulation (EU) 2018/858.

2.2 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificates and information packages annexed thereto as set out in Appendix 4 of this Annex.

2.3 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be assessed in accordance with the specific conditions laid down in paragraph 1 of this Appendix where the provisions defined for IEPC in the respective paragraphs shall be applied unless stated otherwise.

2.4 Notwithstanding the provisions in paragraph 2.3 of this Appendix, the following provisions shall be applied:

(a) Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked only for individual types of IHPC Type 1 instead of families since definition of families is not allowed for IHPCs Type 1 in accordance with paragraph 4.4 of this Annex.

(b) The allocation of the number of tests to be performed to a individual type shall be agreed between the manufacturer and the approval authority.

(c) All references to families in the respective paragraphs shall be interpreted as references to individual types.

(d) The type approved efficiency $\eta_{A,TA}$ shall be calculated by the arithmetic mean value of the two efficiency figures determined in accordance with paragraphs 4.3.5 and 4.3.6 and recorded in the information document during component certification. For these two efficiency figures the post-processing steps described in paragraph 4.4.2.3 of this Annex shall not be performed.

▼**M3**

3. Battery systems or representative battery subsystems

3.1 Every battery system or representative battery subsystem shall be so manufactured as to conform to the approved type with regard to the description as given in the certificate and its annexes. The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply with those set out in Article 31 of Regulation (EU) 2018/858.

3.2 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificates and information packages annexed thereto as set out in Appendix 5 of this Annex.

3.3 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be assessed in accordance with the specific conditions laid down in this paragraph.

3.4 The component manufacturer shall test annually at least the number of units indicated in Table 2 based on the total annual production number of battery systems or representative battery subsystems produced by the component manufacturer. For the purpose of establishing the annual production numbers, only battery systems or representative battery subsystems which fall under the requirements of this Regulation and for which no standard values were used shall be considered.

Table 2

Sample size conformity testing

Total annual production of battery systems or representative battery subsystems	Annual number of tests	Alternatively
0 – 3 000	n.a.	1 test every 3 years (*)
3 001 – 6 000	n.a.	1 test every 2 years (*)
6 001 – 12 000	1	n.a.
12 001 – 30 000	2	n.a.
30 001 – 60 000	3	n.a.
60 001 – 90 000	4	n.a.
90 001 – 120 000	5	n.a.
120 001 – 150 000	6	n.a.
> 150 000	7	n.a.

(*) The CoP test shall be performed in the first year

3.5. For the purpose of the conformity of the certified CO_2 emissions and fuel consumption related properties testing the approval authority shall identify together with the component manufacturer the type(s) of battery system or representative battery subsystem to be tested. The approval authority shall ensure that the selected type(s) of battery system or representative battery subsystem is manufactured to the same standards as for serial production.

▼M3

3.6 If the result of a test performed in accordance with point 3.7 is higher than the one specified in point 3.7.4., 3 additional units from the same type shall be tested. If any of them fails, Article 23 shall apply.

3.7 Production conformity testing of battery system or representative battery subsystem

3.7.1 Boundaries conditions

All boundary conditions as specified in this Annex for the certification testing shall apply.

3.7.2 Test run

Two different tests shall be performed.

For test 1 the test procedure for rated capacity shall be performed in accordance with paragraph 5.4.1 of this Annex.

For test 2 the following procedure shall be performed:

(a) Test 2 shall be performed after test 1.

(b) After the battery UUT was fully charged in accordance with the specifications of the component manufacturer and thermal equilibration in accordance with paragraph 5.1.1 was reached, a standard cycle in accordance with paragraph 5.3 shall be performed.

(c) Within a period of 1 to 3 hours after the end of the standard cycle, the actual test run shall be started. Otherwise, the procedure in the preceding subpoint (b) shall be repeated.

(d) In order to reach the required SOC levels for testing as defined in subpoints (e) and (f) from the initial condition of the battery UUT, it shall be discharged at a constant current rate of 3C for HPBS and of 1C for HEBS.

(e) For HPBS the actual test run shall consist of a 20-second discharge at 80 % SOC with the maximum discharge current I_{dischg_max} as documented during component type approval and of a 20-second charge at 20 % SOC with the maximum charge current I_{chg_max} as documented during component type approval.

(f) For HEBS the actual test run shall consist of a 120-second discharge at 90 % SOC with the maximum discharge current I_{dischg_max} as documented during component type approval and of a 120-second charge at 20 % SOC with the maximum charge current I_{chg_max} as documented during component type approval.

(g) During the actual test run described in subpoints (e) and (f) above, the discharging and charging currents shall be recorded over the respective durations specified.

3.7.3 Post-processing of results

For HPBS the discharging current at 80 % SOC and the charging current at 20 % SOC shall be averaged over the measurement period of 20 seconds.

▼**M3**

For HEBS the discharging current at 90 % SOC and the charging current at 20 % SOC shall be averaged over the measurement period of 120 seconds.

Absolute numbers shall be used for both average values, discharging and charging current.

3.7.4 Evaluation of results

The conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when all of the following criteria are fulfilled:

(a) $C_{CoP} \geq 0{,}95\ C_{TA}$

where:

C_{CoP} Rated capacity determined in accordance with paragraph 3.7.2 [Ah]

C_{TA} Rated capacity determined during component type approval [Ah]

(b) $(\eta_{BAT,CoP} - \eta_{BAT,TA}) \leq 3\%$

where:

$\eta_{BAT,CoP}$ Round trip efficiency determined in accordance with paragraph 3.7.2 [-]

$\eta_{BAT,TA}$ Round trip efficiency determined during component type approval [-]

(c) $I_{dischg\_max,CoP} \geq I_{dischg\_max,TA}$

where:

$I_{dischg\_max,CoP}$ Maximum discharge current determined in accordance with paragraph 3.7.2 (at 80 % SOC for HPBS and at 90 % SOC for HEBS) [A]

$I_{dischg\_max,TA}$ Maximum discharge current determined during component type approval (at 80 % SOC for HPBS and at 90 % SOC for HEBS) [A]

(d) $I_{chg\_max,CoP} \geq I_{chg\_max,TA}$

where:

$I_{chg\_max,CoP}$ Maximum charge current determined in accordance with paragraph 3.7.2 (at 20 % SOC) [A]

$I_{chg\_max,TA}$ Maximum charge current determined during component type approval (at 20 % SOC) [A]

4. Capacitor systems

4.1 Every capacitor systems shall be so manufactured as to conform to the approved type with regard to the description as given in the certificate and its annexes. The conformity of the certified CO_2 emissions and fuel consumption related properties procedures shall comply with those set out in Article 31 of Regulation (EU) 2018/858.

▼**M3**

4.2 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be checked on the basis of the description in the certificates and information packages annexed thereto as set out in Appendix 6 of this Annex.

4.3 Conformity of the certified CO_2 emissions and fuel consumption related properties shall be assessed in accordance with the specific conditions laid down in this paragraph.

4.4 The component manufacturer shall test annually at least the number of units indicated in Table 3 based on the total annual production number of capacitor systems produced by the component manufacturer. For the purpose of establishing the annual production numbers, only capacitor systems which fall under the requirements of this Regulation and for which no standard values were used shall be considered.

Table 3

Sample size conformity testing

Total annual production of capacitor systems	Annual number of tests	Alternatively
0 – 3 000	n.a.	1 test every 3 years (*)
3 001 – 6 000	n.a.	1 test every 2 years (*)
6 001 – 12 000	1	n.a.
12 001 – 30 000	2	n.a.
30 001 – 60 000	3	n.a.
60 001 – 90 000	4	n.a.
90 001 – 120 000	5	n.a.
120 001 – 150 000	6	n.a.
> 150 000	7	n.a.

(*) The CoP test shall be performed in the first year

4.5. For the purpose of the conformity of the certified CO_2 emissions and fuel consumption related properties testing the approval authority shall identify together with the component manufacturer the type(s) of capacitor systems to be tested. The approval authority shall ensure that the selected type(s) of capacitor systems is manufactured to the same standards as for serial production.

4.6 If the result of a test performed in accordance with point 4.7 is higher than the one specified in point 4.7.4., 3 additional units from the same type shall be tested. If any of them fails, Article 23 shall apply.

4.7 Production conformity testing of capacitor systems

4.7.1 Boundaries conditions

All boundary conditions as specified in this Annex for the certification testing shall apply.

▼**M3**

4.7.2 Test run

The test procedure shall be performed in accordance with paragraph 6.3 of this Annex.

4.7.3 Post-processing of results

The post-processing of results shall be performed in accordance with paragraph 6.4 of this Annex.

4.7.4 Evaluation of results

The conformity of the certified CO_2 emissions and fuel consumption related properties test is passed when all of the following criteria are fulfilled:

(a) $(C_{CoP} / C_{TA}) - 1 < \pm 3\ \%$

where:

C_{CoP} Capacitance determined in accordance with paragraph 4.7.2 [F]

C_{TA} Capacitance determined during component type approval [F]

(b) $(R_{CoP} / R_{TA}) - 1 < \pm 3\ \%$

where:

R_{CoP} Internal resistance determined in accordance with paragraph 4.7.2 [Ohm]

R_{TA} Internal resistance determined during component type approval [Ohm]

▼M3

Appendix 13

Family concept

1. Electric machine systems and IEPCs

1.1. General

A family of electric machine systems or IEPCs is characterised by design and performance parameters. These shall be common to all members within the family. The component manufacturer may decide which electric machine systems or IEPCs belong to a family, as long as the membership criteria listed in this Appendix are respected. The related family shall be approved by the Approval Authority. The component manufacturer shall provide to the Approval Authority the appropriate information relating to the members of the family.

1.2. Special cases

In some cases there may be interaction between parameters. This shall be taken into consideration to ensure that electric machine systems or IEPCs with similar characteristics are included within the same family. These cases shall be identified by the component manufacturer and notified to the Approval Authority. It shall then be taken into account as a criterion for creating a new family of electric machine systems or IEPCs.

In the case of devices or features, which are not listed in paragraph 1.4 and which have a strong influence on the level of performance and/or the electric power consumption, the respective devices or features shall be identified by the component manufacturer on the basis of good engineering practice, and shall be notified to the Approval Authority. It shall then be taken into account as a criterion for creating a new family of electric machine systems or IEPCs.

1.3. Family concept

The family concept defines criteria and parameters enabling the component manufacturer to group electric machine systems or IEPCs into families with similar or equal data relevant for CO_2-emissions or energy consumption.

1.4. Special provisions regarding representativeness

The Approval Authority may conclude that the performance parameters and the electric power consumption of the family of electric machine systems or IEPCs can best be characterised by additional testing. In this case, the component manufacturer shall submit the appropriate information to determine the electric machine system or IEPC within the family likely to best represent the family. The Approval Authority may based on this information also conclude that it is required for the component manufacturer to create a new family of electric machine systems or IEPCs consisting of less members in order to be more representative.

If members within a family incorporate other features which may be considered to affect the performance parameters and/or the electric power consumption, these features shall also be identified and taken into account in the selection of the parent.

1.5. Parameters defining a family of electric machine systems or IEPCs

In addition to the parameters listed below, the component manufacturer may introduce additional criteria allowing the definition of families of more restricted size. These parameters are not necessarily parameters that have an influence on the level of performance and/or the electric power consumption.

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1.5.1. The following criteria shall in principal be the same to all members within a family of electric machine systems or IEPCs:

(a) Electric Machine: Rotor, Stator, Windings in dimensions, design, material, etc.

(b) Inverter: Power Modules, Conductive bars in dimensions, design, material, etc.

(c) Internal cooling system: layout, dimension and material of cooling fins, ribs, and pins

(d) Internal fans: layout and dimension

(e) Inverter Software: Basic calibration which consists of temperature models (electric machine and inverter), derating limits, torque path (transfer of command torque to phase current), flux calibration, current control, voltage modulation, sensor specific calibration (only allowed if sensor is changed)

(f) Gear related parameters (only for IEPCs): in accordance with definitions set out in Annex VI.

Changes to the components as mentioned at (a) through (f) are only acceptable as long as sound engineering rationale can be provided to prove that the respective change does not negatively affect the performance parameters and/or the electric power consumption.

1.5.2. The following criteria shall be common to all members within a family of electric machine systems or IEPCs. The application of a specific range to the parameters listed below is permitted after approval of the Approval Authority:

(a) Output shaft interface: any changes allowed;

(b) End shields:

For the internal design it must be checked if passive cooling elements or air flow at the inner side of the end shields are affected by changes.

For the external design screws, suspension points, flange design have no influence on performance if no passive cooling elements are removed or changed;

(c) Bearings: Changes allowed as long as number and type of bearings remain the same;

(d) Shaft: Changes allowed as long as active or passive cooling is not affected;

(e) High voltage connection: Changes regarding position or type of the high voltage connection allowed;

(f) Housing: Changes of the housing or number, type and position of screws or mounting points allowed as long as no passive cooling elements are removed or changed;

(g) Sensor: Changes allowed, if certified performance is not changed;

(h) Inverter housing: Changes of the housing or number, type and position of screws or mounting points allowed as long as no passive cooling elements are removed or changed or the inner layout of the electric active parts is not changed;

▼**M3**

(i) Inverter high voltage connection: Changes regarding position or type of the high voltage connection allowed as long as the layout or position of the active parts or cooling elements (active/passive) is not changed;

(j) Inverter software: All software changes which do not change the basic calibration of the electric machine (definition see above) are allowed. Notwithstanding the previous provisions, limitations of output power are allowed for members within a family of electric machine systems or IEPCs;

(k) Inverter sensor: Changes allowed, if certified performance is not changed;

(l) Oil viscosity: for all oils that are specified for the factory fill, the kinematic viscosity at the same temperature shall be less or equal to 110 % of the kinematic viscosity of the oil used for component certification as documented in the respective information document (within the specified tolerance band for KV100);

(m) Maximum torque curve

The torque values at each rotational speed of the maximum torque curve of the parent determined in accordance with paragraph 4.2.2.4 of this Annex shall be equal or higher than for all other members within the same family at the same rotational speed over the whole rotational speed range. Torque values of other members within the same family within a tolerance of +40 Nm or +4 %, whatever is larger, above the maximum torque of the parent at a specific rotational speed are considered as equal;

(n) Minimum torque curve

The torque values at each rotational speed of the minimum torque curve of the parent determined in accordance with paragraph 4.2.2.4 of this Annex shall be equal or lower than for all other members within the same family at the same rotational speed over the whole rotational speed range. Torque values of other members within the same family within a tolerance of -40 Nm or -4 %, whatever is larger, below the minimum torque of the parent at a specific rotational speed are considered as equal;

(o) Minimum number of points in the EPMC map:

All members within the same family shall have a minimum coverage of 60 % of the points (rounded up to the next whole number) of the EPMC map (i.e. where the EPMC map of the parent is applied to other members) located within the boundaries of their respective maximum and minimum torque curves determined in accordance with paragraph 4.2.2.4 of this Annex.

1.6. Choice of the parent

The parent of one family of electric machine systems or IEPCs shall be member with the highest overall maximum torque determined in accordance with paragraph 4.2.2 of this Annex.

▼M3

Appendix 14

Markings and numbering

1. Markings

In the case of an electric powertrain component being type approved in accordance with this Annex, the component shall bear:

1.1. The manufacturer's name or trade mark

1.2. The make and identifying type indication as recorded in the information referred to in paragraph 0.2 and 0.3 of Appendixes 2 to 6 of this Annex

1.3. The certification mark (if applicable) as a rectangle surrounding the lower-case letter 'e' followed by the distinguishing number of the Member State which has granted the certificate:

1 for Germany;

2 for France;

3 for Italy;

4 for the Netherlands;

5 for Sweden;

6 for Belgium;

7 for Hungary;

8 for Czechia;

9 for Spain;

12 for Austria;

13 for Luxembourg;

17 for Finland;

18 for Denmark;

19 for Romania;

20 for Poland;

21 for Portugal;

23 for Greece;

24 for Ireland;

25 for Croatia;

26 for Slovenia;

27 for Slovakia;

29 for Estonia;

32 for Latvia;

34 for Bulgaria;

36 for Lithuania;

49 for Cyprus;

50 for Malta

1.4. The certification mark shall also include in the vicinity of the rectangle the 'base certification number' as specified for Section 4 of the type-approval number set out in Annex IV to Regulation (EU) 2020/683 preceded by the two figures indicating the sequence number assigned to the latest technical amendment to this Regulation and by an alphabetical character indicating the part for which the certificate has been granted:

For this Regulation, the sequence number shall be 02.

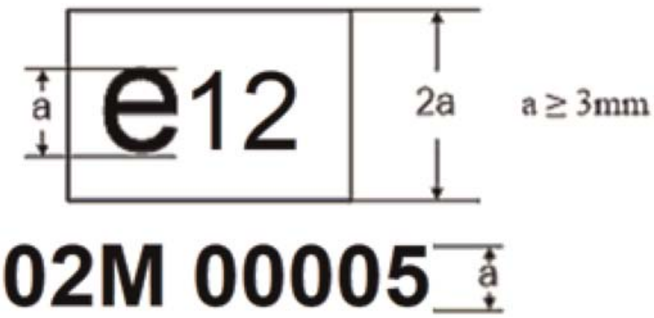
For this Regulation, the alphabetical character shall be the one laid down in Table 1.

Table 1

M	electric machine system (EMS)
I	integrated electric powertrain component (IEPC)
H	integrated HEV powertrain component (IHPC) Type 1
B	battery system
A	capacitor system

▼M3

1.4.1. Example and dimensions of the certification mark



The above certification mark affixed to an electric powertrain component shows that the type concerned has been approved in Austria (e12), pursuant to this Regulation. The first two digits (02) are indicating the sequence number assigned to the latest technical amendment to this Regulation. The following letter indicates that the certificate was granted for an electric machine system (M). The last five digits (00005) are those allocated by the type-approval authority to the electric machine system as the base certification number.

1.5 Upon request of the applicant for a certificate and after prior agreement with the type-approval authority other type sizes than indicated in 1.4.1 may be used. Those other type sizes shall remain clearly legible.

1.6 The markings, labels, plates or stickers must be durable for the useful life of the electric powertrain component and must be clearly legible and indelible. The manufacturer shall ensure that the markings, labels, plates or sticker cannot be removed without destroying or defacing them.

1.7 The certification mark shall be visible when the electric powertrain component is installed on the vehicle and shall be affixed to a part necessary for normal operation and not normally requiring replacement during component life.

2. Numbering:

2.1. Certification number for an electric powertrain component shall comprise the following:

eX*YYYY/YYYY*ZZZZ/ZZZZ*X*00000*00

section 1	section 2	section 3	Additional letter to section 3	section 4	section 5
Indication of country issuing the certificate	HDV CO_2 determination Regulation ‘2017/2400’	Latest amending Regulation (ZZZZ/ZZZZ)	See Table 1 of this appendix	Base certification number 00000	Extension 00

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Appendix 15

Input parameters for the simulation tool

Introduction

This Appendix describes the list of parameters to be provided by the component manufacturer as input to the simulation tool. The applicable XML schema as well as example data are available at the dedicated electronic distribution platform.

Definitions

(1) 'parameter ID': Unique identifier as used in the simulation tool for a specific input parameter or set of input data

(2) 'type': Data type of the parameter

string .... sequence of characters in ISO8859-1 encoding

token .... sequence of characters in ISO8859-1 encoding, no leading/trailing whitespace

date .... date and time in UTC time in the format: YYYY-MM-DD*T*HH:MM:SS*Z* with italic letters denoting *fixed characters* e.g. '2002-05-30*T*09:30:10*Z*'

integer .... value with an integral data type, no leading zeros, e.g. '1800'

double, X .... fractional number with exactly X digits after the decimal sign ('.') and no leading zeros e.g. for 'double, 2': '2345,67'; for 'double, 4': '45,6780'

(3) 'unit' … physical unit of the parameter

Set of input parameters for Electric machine system

Table 1

Input parameters 'Electric machine system/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P450	token	[-]	
Model	P451	token	[-]	
CertificationNumber	P452	token	[-]	
Date	P453	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P454	token	[-]	Manufacturer specific input regarding the tools used for evaluation and handling of measured component data

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Parameter name	Parameter ID	Type	Unit	Description/Reference
ElectricMachineType	P455	string	[-]	Determined in accordance with point 21 of paragraph 2 of this Annex. Allowed values: 'ASM', 'ESM', 'PSM', 'RM'
CertificationMethod	P456	string	[-]	Allowed values: 'Measurement', 'Standard values'
R85RatedPower	P457	integer	[W]	Determined in accordance with paragraph 1.9 of Annex 2 to UN Regulation No. 85 Rev. 1
RotationalInertia	P458	double, 2	[kgm^2]	Determined in accordance with point 8 of Appendix 8 of this Annex.
DcDcConverterIncluded	P465	boolean	[-]	Set to 'true' where a DC/DC converter is part of the electric machine system, in accordance with paragraph 4.1 of this Annex
IHPCType	P466	string	[-]	Allowed values: 'None', 'IHPC Type 1'

Table 2

Input parameters 'Electric machine system/VoltageLevels' for each voltage level measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
VoltageLevel	P467	integer	[V]	Where the parameter 'Certification-Method' is 'Standard values', no input needs to be provided.
ContinuousTorque	P459	double, 2	[Nm]	
TestSpeedContinuousTorque	P460	double, 2	[1/min]	
OverloadTorque	P461	double, 2	[Nm]	
TestSpeedOverloadTorque	P462	double, 2	[1/min]	
OverloadDuration	P463	double, 2	[s]	

Table 3

Input parameters 'Electric machine system/MaxMinTorque' for each operating point and for each voltage level measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputShaftSpeed	P468	double, 2	[1/min]	
MaxTorque	P469	double, 2	[Nm]	
MinTorque	P470	double, 2	[Nm]	

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Table 4

Input parameters 'Electric machine system/DragTorque' for each operating point

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputShaftSpeed	P471	double, 2	[1/min]	
DragTorque	P472	double, 2	[Nm]	

Table 5

Input parameters 'Electric machine system/ElectricPowerMap' for each operating point and for each voltage level measured.

In the case of an IHPC Type 1 (in accordance with the definition set out in sub point (42) of point 2 of this Annex), for each operating point, for each voltage level measured and for each forward gear.

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputShaftSpeed	P473	double, 2	[1/min]	
Torque	P474	double, 2	[Nm]	
ElectricPower	P475	double, 2	[W]	

Table 6

Input parameters 'Electric machine system/Conditioning' for each cooling circuit with connection to an external heat exchanger

Where the parameter 'CertificationMethod' is 'Standard values', no input needs to be provided.

Parameter name	Parameter ID	Type	Unit	Description/Reference
CoolantTempInlet	P476	integer	[°C]	Determined in accordance with paragraphs 4.1.5.1 and 4.3.6 of this Annex.
CoolingPower	P477	integer	[W]	Determined in accordance with paragraphs 4.1.5.1 and 4.3.6 of this Annex.

Set of input parameters for IEPC

Table 1

Input parameters 'IEPC/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P478	token	[-]	
Model	P479	token	[-]	
CertificationNumber	P480	token	[-]	
Date	P481	dateTime	[-]	Date and time when the component-hash is created

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Parameter name	Parameter ID	Type	Unit	Description/Reference
AppVersion	P482	token	[-]	Manufacturer specific input regarding the tools used for evaluation and handling of measured component data
ElectricMachineType	P483	string	[-]	Determined in accordance with point 21 of paragraph 2 of this Annex. Allowed values: ‘ASM’, ‘ESM’, ‘PSM’, ‘RM’
CertificationMethod	P484	string	[-]	Allowed values: ‘Measured for complete component’, ‘Measured for EM and standard values for other components’, ‘Standard values for all components’
R85RatedPower	P485	integer	[W]	Determined in accordance with paragraph 1.9 of Annex 2 to UN Regulation No. 85
RotationalInertia	P486	double, 2	[kgm^2]	Determined in accordance with point 8 of Appendix 8 of this Annex.
DifferentialIncluded	P493	boolean	[-]	Set to ‘true’ in the case a differential is part of the IEPC
DesignTypeWheelMotor	P494	boolean	[-]	Set to ‘true’ in the case of an IEPC design type wheel motor
NrOf DesignTypeWheelMotorMeasured	P495	integer	[-]	Input only relevant in the case of an IEPC design type wheel motor, in accordance with paragraph 4.1.1.2 of this Annex. Allowed values: ‘1’, ‘2’

Table 2

Input parameters ‘IEPC/Gears’ for each forward gear

Parameter name	Parameter ID	Type	Unit	Description/Reference
GearNumber	P496	integer	[-]	
Ratio	P497	double, 3	[-]	Ratio of electric machine rotor speed over IEPC output shaft speed
MaxOutputShaftTorque	P498	integer	[Nm]	optional
MaxOutputShaftSpeed	P499	integer	[1/min]	optional

Table 3

Input parameters ‘IEPC/VoltageLevels’ for each voltage level measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
VoltageLevel	P500	integer	[V]	Where the parameter ‘CertificationMethod’ is ‘Standard values for all components’, no input needs to be provided.

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Parameter name	Parameter ID	Type	Unit	Description/Reference
ContinuousTorque	P487	double, 2	[Nm]	
TestSpeedContinuousTorque	P488	double, 2	[1/min]	
OverloadTorque	P489	double, 2	[Nm]	
TestSpeedOverloadTorque	P490	double, 2	[1/min]	
OverloadDuration	P491	double, 2	[s]	

Table 4

Input parameters 'IEPC/MaxMinTorque' for each operating point and for each voltage level measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputShaftSpeed	P501	double, 2	[1/min]	
MaxTorque	P502	double, 2	[Nm]	
MinTorque	P503	double, 2	[Nm]	

Table 5

Input parameters 'IEPC/DragTorque' for each operating point and for each forward gear measured (optional gear dependent measurement in accordance with paragraph 4.2.3)

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputShaftSpeed	P504	double, 2	[1/min]	
DragTorque	P505	double, 2	[Nm]	

Table 6

Input parameters 'IEPC/ElectricPowerMap' for each operating point, for each voltage level measured and for each forward gear

Parameter name	Parameter ID	Type	Unit	Description/Reference
OutputShaftSpeed	P506	double, 2	[1/min]	
Torque	P507	double, 2	[Nm]	
ElectricPower	P508	double, 2	[W]	

Table 7

Input parameters 'IEPC/Conditioning' for each cooling circuit with connection to an external heat exchanger

Where the parameter 'CertificationMethod' is 'Standard values for all components', no input needs to be provided.

Parameter name	Parameter ID	Type	Unit	Description/Reference
CoolantTempInlet	P509	integer	[°C]	Determined in accordance with paragraphs 4.1.5.1 and 4.3.6 of this Annex.

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Parameter name	Parameter ID	Type	Unit	Description/Reference
CoolingPower	P510	integer	[W]	Determined in accordance with paragraphs 4.1.5.1 and 4.3.6 of this Annex.

Set of input parameters for Battery system

Table 1

Input parameters 'Battery system/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P511	token	[-]	
Model	P512	token	[-]	
CertificationNumber	P513	token	[-]	
Date	P514	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P515	token	[-]	Manufacturer specific input regarding the tools used for evaluation and handling of measured component data
CertificationMethod	P517	string	[-]	Allowed values: 'Measured', 'Standard values'
BatteryType	P518	string	[-]	Allowed values: 'HPBS', 'HEBS'
RatedCapacity	P519	double, 2	[Ah]	
ConnectorsSubsystemsIncluded	P520	boolean	[-]	Only relevant if representative battery sub-system is tested: Set to 'true' if representative cable harness for connecting battery sub-systems was included in testing. Always set to 'true' if complete battery system was tested.
JunctionboxIncluded	P511	boolean	[-]	Only relevant if representative battery sub-system is tested: Set to 'true' if representative junction box with shut-off device and fuses was included in testing. Always set to 'true' if complete battery system was tested.
TestingTemperature	P521	integer	[°C]	Determined in accordance with paragraph 5.1.4 of this Annex. Where the parameter 'CertificationMethod' is 'Standard values', no input needs to be provided.

▼**M3**

Table 2

Input parameters ‘Battery system/OCV’ for each SOC level measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
SOC	P522	integer	[%]	
OCV	P523	double, 2	[V]	

Table 3

Input parameters ‘Battery system/DCIR’ for each SOC level measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
SOC	P524	integer	[%]	Where the parameter ‘Certification-Method’ is ‘Standard values’, the same DCIR values shall be provided for two different SOC values of 0 % and 100 %.
DCIR R_{I2}	P525	double, 2	[mOhm]	Where the parameter ‘Certification-Method’ is ‘Standard values’, the DCIR value determined in accordance with subpoint (1)(d) of Appendix 10 shall be provided.
DCIR R_{I10}	P526	double, 2	[mOhm]	Where the parameter ‘Certification-Method’ is ‘Standard values’, the DCIR value determined in accordance with subpoint (1)(d) of Appendix 10 shall be provided.
DCIR R_{I20}	P527	double, 2	[mOhm]	Where the parameter ‘Certification-Method’ is ‘Standard values’, the DCIR value determined in accordance with subpoint (1)(d) of Appendix 10 shall be provided.
DCIR R_{I120}	P528	double, 2	[mOhm]	Optional, only required for batteries of type HEBS. In the event the parameter ‘Certification-Method’ is ‘Standard values’, the DCIR value determined in accordance with subpoint (1)(d) of Appendix 10 shall be provided.

Table 4

Input parameters ‘Battery system/Current limits’ for each SOC level measured

Parameter name	Parameter ID	Type	Unit	Description/Reference
SOC	P529	integer	[%]	Where the parameter ‘Certification-Method’ is ‘Standard values’, the same values for MaxChargingCurrent as well as MaxDischargingCurrent shall be provided for two different SOC values of 0 % and 100 %.
MaxChargingCurrent	P530	double, 2	[A]	
MaxDischargingCurrent	P531	double, 2	[A]	

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Set of input parameters for Capacitor system

Table 1

Input parameters 'Capacitor system/General'

Parameter name	Parameter ID	Type	Unit	Description/Reference
Manufacturer	P532	token	[-]	
Model	P533	token	[-]	
CertificationNumber	P534	token	[-]	
Date	P535	dateTime	[-]	Date and time when the component-hash is created
AppVersion	P536	token	[-]	Manufacturer specific input regarding the tools used for evaluation and handling of measured component data
CertificationMethod	P538	string	[-]	Allowed values: 'Measurement', 'Standard values'
Capacitance	P539	double, 2	[F]	
InternalResistance	P540	double, 2	[Ohm]	
MinVoltage	P541	double, 2	[V]	
MaxVoltage	P542	double, 2	[V]	
MaxChargingCurrent	P543	double, 2	[A]	
MaxDischargingCurrent	P544	double, 2	[A]	
TestingTemperature	P532	integer	[°C]	Determined in accordance with paragraph 6.1.3 of this Annex. Where the parameter 'Certification-Method' is 'Standard values', no input needs to be provided.

(*) determined in accordance with points 4.3.5 and 4.3.6 of this Annex

(**) determined in accordance with points 5.4.1.4 of this Annex

(***) UN Regulation No. 100 of the Economic Commission for Europe of the United Nations (UNECE) — Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric powertrain (OJ L449, 15.12.2021 p. 1).

▼B

ANNEX XI

AMENDMENTS TO DIRECTIVE 2007/46/EC

(1) In Annex I the following point 3.5.7 is inserted:

'3.5.7 CO_2 emissions and fuel consumption certification (for heavy-duty vehicles, as specified in Article 6 of Commission Regulation (EU) 2017/2400)

3.5.7.1 Simulation tool license number:'

(2) In Annex III, in Part I, A (Categories M and N), the following points 3.5.7. and 3.5.7.1. are inserted:

'3.5.7 CO_2 emissions and fuel consumption certification (for heavy-duty vehicles, as specified in Article 6 of Commission Regulation (EU) 2017/2400)

3.5.7.1 Simulation tool licence number:'

(3) In Annex IV, Part I, is amended as follows:

(a) the row 41A is replaced by the following:

'41A	Emissions (Euro VI) heavy duty vehicles/access to information	Regulation (EC) No 595/2009 Regulation (EU) No 582/2011	X (9)	X (9)	X	X (9)	X (9)	X'				

(b) the following row 41B is inserted:

'41B	CO_2 simulation tool licence (heavy-duty vehicles)	Regulation (EC) 595/2009 Regulation (EU) 2017/2400					X (16)	X'				

(c) the following explanatory note 16 is added:

'(16) For vehicles with a technically permissible maximum laden mass from 7 500 kg'

(4) Annex IX is amended as follows:

(a) in Part I, Model B, SIDE 2, VEHICLE CATEGORY N_2, the following point 49 is inserted:

'49. Cryptographic hash of the manufacturer's record file ....'

(b) in Part I, Model B, SIDE 2, VEHICLE CATEGORY $N_{3,}$ the following point 49 is inserted:

'49. Cryptographic hash of the manufacturer's record file ....'

(5) in Annex XV, in point 2, the following row is inserted:

'46B	Rolling resistance determination	Regulation (EU) 2017/2400, Annex X'