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From: Secretary-General of the European Commission,  
signed by Mr Jordi AYET PUIGARNAU, Director

date of receipt: 19 December 2016

To: Mr Jeppe TRANHOLM-MIKKELSEN, Secretary-General of the Council of  
the European Union

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Subject: ANNEXES to the Commission Delegated Regulation (EU) .../...  
supplementing Regulation (EU) 2016/1628 of the European Parliament and  
of the Council with regard to technical and general requirements relating to  
emission limits and type-approval for internal combustion engines for non-  
road mobile machinery

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Delegations will find attached document C(2016) 8381 final ANNEXES 8 to 17.

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Brussels, 19.12.2016  
C(2016) 8381 final

ANNEXES 8 to 17

## **ANNEXES**

**to the**

**Commission Delegated Regulation (EU) .../...**

**supplementing Regulation (EU) 2016/1628 of the European Parliament and of the Council with regard to technical and general requirements relating to emission limits and type-approval for internal combustion engines for non-road mobile machinery**

## ANNEX VIII

### Performance requirements and test procedures for dual-fuel engines

#### 1. Scope

This Annex shall apply for dual-fuel engines as defined in Article 3(18) of Regulation (EU) 2016/1628 when they are being operated simultaneously on both a liquid and a gaseous fuel (dual-fuel mode).

This Annex shall not apply for testing engines, including dual-fuel engines, when they are being operated solely on liquid or solely on gaseous fuels (ie when the GER is either 1 or 0 according to the type of fuel). In this case the requirements are the same as for any single-fuel engine.

Type approval of engines operated simultaneously on a combination of more than one liquid fuel and a gaseous fuel or a liquid fuel and more than one gaseous fuel shall follow the procedure for new technologies or new concepts given in Article 33 of Regulation (EU) 2016/1628.

#### 2. Definitions and abbreviations

For the purposes of this Annex the following definitions shall apply:

- 2.1. "GER (Gas Energy Ratio)" has the meaning defined in Article 3(20) of Regulation (EU) 2016/1628 based on the lower heating value;
- 2.2. "GER<sub>cycle</sub>" means the average GER when operating the engine on the applicable engine test cycle;
- 2.3. "Dual-fuel Type 1A engine" means either:
  - (a) a dual-fuel engine of a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the hot-start NRTC test-cycle with an average gas energy ratio that is not lower than 90 % ( $GER_{NRTC, hot} \geq 0,9$ ) and that does not idle using exclusively liquid fuel, and that has no liquid-fuel mode, or;
  - (b) a dual-fuel engine of any (sub-) category other than a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the NRSC with an average gas energy ratio that is not lower than 90 % ( $GER_{NRSC} \geq 0,9$ ) and that does not idle using exclusively liquid fuel, and that has no liquid-fuel mode;
- 2.4. "Dual-Fuel Type 1B engine" means either:
  - (a) a dual-fuel engine of a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the hot-start NRTC test-cycle with an average gas energy ratio that is not lower than 90 % ( $GER_{NRTC, hot} \geq 0,9$ ) and that does not idle using exclusively liquid fuel in dual-fuel mode, and that has a liquid-fuel mode, or;
  - (b) a dual-fuel engine of any (sub-) category other than a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the NRSC with an average gas energy ratio that

is not lower than 90 % ( $GER_{NRSC} \geq 0,9$ ) and that does not idle using exclusively liquid fuel in dual-fuel mode, and that has a liquid-fuel mode;

2.5. "Dual-Fuel Type 2A engine" means either:

- (a) a dual-fuel engine of a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the hot-start NRTC test-cycle with an average gas energy ratio between 10 % and 90 % ( $0,1 < GER_{NRTC, hot} < 0,9$ ) and that has no liquid-fuel mode or that operates over the hot-start NRTC test-cycle with an average gas energy ratio that is not lower than 90 % ( $GER_{NRTC, hot} \geq 0,9$ ), but that idles using exclusively liquid fuel, and that has no liquid-fuel mode, or;
- (b) a dual-fuel engine of any (sub-) category other than a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the NRSC with an average gas energy ratio between 10 % and 90 % ( $0,1 < GER_{NRSC} < 0,9$ ), and that has no liquid-fuel mode or that operates over the NRSC with an average gas energy ratio that is not lower than 90 % ( $GER_{NRSC} \geq 0,9$ ), but that idles using exclusively liquid fuel, and that has no liquid-fuel mode;

2.6. "Dual-Fuel Type 2B engine" means either:

- (a) a dual-fuel engine of a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the hot-start NRTC test-cycle with an average gas energy ratio between 10 % and 90 % ( $0,1 < GER_{NRTC, hot} < 0,9$ ) and that has a liquid-fuel mode or that operates over the hot-start NRTC test-cycle with an average gas energy ratio that is not lower than 90 % ( $GER_{NRTC, hot} \geq 0,9$ ), and that has a liquid-fuel mode but that can idle using exclusively liquid fuel in dual-fuel mode, or;
- (b) a dual-fuel engine of any (sub-) category other than a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the NRSC with an average gas energy ratio between 10 % and 90 % ( $0,1 < GER_{NRSC} < 0,9$ ), and that has no liquid-fuel mode or that operates over the NRSC with an average gas energy ratio that is not lower than 90 % ( $GER_{NRSC} \geq 0,9$ ), and that has a liquid-fuel mode but that can idle using exclusively liquid fuel in dual-fuel mode;

2.7. "Dual-Fuel Type 3B engine" means either:

- (a) a dual-fuel engine of a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the hot-start NRTC test-cycle with an average gas energy ratio that does not exceed 10 % ( $GER_{NRTC, hot} \leq 0,1$ ) and that has a liquid-fuel mode, or;
- (b) a dual-fuel engine of any (sub-) category other than a sub-category of NRE  $19 \leq kW \leq 560$ , that operates over the NRSC with an average gas energy ratio that does not exceed 10 % ( $GER_{NRSC} \leq 0,1$ ) and that has a liquid-fuel mode;

3. Dual-fuel specific additional approval requirements

3.1. Engines with operator-adjustable control of  $GER_{cycle}$ .

In the case for a given engine type the value of  $GER_{cycle}$  can be reduced from the maximum by an operator-adjustable control, the minimum  $GER_{cycle}$  shall not be limited but the engine shall be capable of meeting the emission limit values at any value of  $GER_{cycle}$  permitted by the manufacturer.

#### 4. General requirements

##### 4.1. Operating modes of dual-fuel engines

###### 4.1.1. Conditions for a dual-fuel engine to operate in liquid mode

A dual-fuel engine may only operate in liquid-fuel mode if, when operating in liquid-fuel mode, it has been certified according to all the requirements of this Regulation concerning operation solely on the specified liquid fuel.

When a dual-fuel engine is developed from an already certified liquid-fuel engine, then a new EU type approval certificate is required in the liquid-fuel mode.

###### 4.1.2. Conditions for a dual-fuel engine to idle using liquid fuel exclusively

4.1.2.1. Dual-fuel Type 1A engines shall not idle using liquid fuel exclusively except under the conditions defined in point 4.1.3. for warm-up and start.

4.1.2.2. Dual-fuel Type 1B engines shall not idle using liquid fuel exclusively in dual-fuel mode.

4.1.2.3. Dual-fuel Types 2A, 2B and 3B engines may idle using liquid fuel exclusively.

###### 4.1.3. Conditions for a dual-fuel engine to warm-up or start using liquid fuel solely

4.1.3.1. A Type 1B, Type 2B, or Type 3B dual-fuel engine may warm-up or start using liquid fuel solely. In the case that the emission control strategy during warm-up or start-up in dual-fuel mode is the same as the corresponding emission control strategy in liquid-fuel mode the engine may operate in dual-fuel mode during warm-up or start-up. If this condition is not met the engine shall only warm-up or start-up using liquid fuel solely when in liquid-fuel mode.

4.1.3.2. A Type 1A or Type 2A dual-fuel engine may warm-up or start-up using liquid fuel solely. However, in that case, the strategy shall be declared as an AECS and the following additional requirements shall be met:

4.1.3.2.1. The strategy shall cease to be active when the coolant temperature has reached a temperature of 343 K (70 °C), or within 15 minutes after it has been activated, whichever occurs first; and

4.1.3.2.2. The service mode shall be activated while the strategy is active.

##### 4.2. Service mode

###### 4.2.1. Conditions for dual-fuel engines to operate in service mode

When an engine is operating in service mode it is subject to an operability restriction and is temporarily exempted from complying with the requirements related to exhaust emissions and NO<sub>x</sub> control described in this Regulation.

###### 4.2.2. Operability restriction in service mode

4.2.2.1. Requirement for engine categories other than IWP, IWA, RLL and RLR

The operability restriction applicable to non-road mobile machinery fitted with a dual-fuel engine of engine categories other than IWP, IWA, RLL and RLR operated in service mode is the one activated by the "severe inducement system" specified in point 5.4. of Appendix 1 of Annex IV.

In order to account for safety concerns and to allow for self-healing diagnostics, use of an inducement override function for releasing full engine power is permitted according to point 5.5. of Appendix 1 of Annex IV.

The operability restriction shall not otherwise be deactivated by either the activation or deactivation of the warning and inducement systems specified in Annex IV.

The activation and the deactivation of the service mode shall not activate or deactivate the warning and inducement systems specified in Annex IV.

#### 4.2.2.2. Requirement for engine categories IWP, IWA, RLL and RLR

For engines of category IWP, IWA, RLL and RLR, in order to account for safety concerns operation in service mode shall be permitted without limitation on engine torque or speed. In this case whenever an operability restriction would have been active according to point 4.2.2.3. the on-board computer log shall record in non-volatile computer memory all incidents of engine operation where the service mode is active in a manner to ensure that the information cannot be intentionally deleted.

It shall be possible for national inspection authorities to read these records with a scan tool.

#### 4.2.2.3. Activation of the operability restriction

The operability restriction shall be automatically activated when the service mode is activated.

In the case where the service mode is activated according to point 4.2.3. because of a malfunction of the gas supply system, the operability restriction shall become active within 30 minutes operating time after the service mode is activated.

In the case where the service mode is activated because of an empty gaseous fuel tank, the operability restriction shall become active as soon as the service mode is activated.

#### 4.2.2.4. Deactivation of the operability restriction

The operability restriction system shall be deactivated when the engine no longer operates in service mode.

#### 4.2.3. Unavailability of gaseous fuel when operating in a dual-fuel mode

In order to permit the non-road mobile machinery to move to a position of safety, upon detection of an empty gaseous fuel tank, or of a malfunctioning gas supply system:

- (a) Dual-fuel engines of Types 1A and 2A shall activate the service mode;

(b) Dual-fuel engines of Types 1B, 2B and 3B shall operate in liquid mode.

#### 4.2.3.1. Unavailability of gaseous fuel – empty gaseous fuel tank

In the case of an empty gaseous fuel tank, the service mode or, as appropriate according to point 4.2.3., the liquid fuel mode shall be activated as soon as the engine system has detected that the tank is empty.

When the gas availability in the tank again reaches the level that justified the activation of the empty tank warning system specified in point 4.3.2., the service mode may be deactivated, or, when appropriate, the dual-fuel mode may be reactivated.

#### 4.2.3.2. Unavailability of gaseous fuel – malfunctioning gas supply

In the case of a malfunctioning gas supply system that causes the unavailability of gaseous fuel, the service mode or, as appropriate according to point 4.2.3., the liquid fuel mode shall be activated when gaseous fuel supply is not available.

As soon as the gaseous fuel supply becomes available the service mode may be deactivated, or, when appropriate, the dual-fuel mode may be reactivated.

### 4.3. Dual-fuel indicators

#### 4.3.1. Dual-fuel operating mode indicator

The non-road mobile machinery shall provide to the operator a visual indication of the mode under which the engine operates (dual-fuel mode, liquid mode, or service mode).

The characteristics and the location of this indicator shall be left to the discretion of the OEM and may be part of an already existing visual indication system.

This indicator may be completed by a message display. The system used for displaying the messages referred to in this point may be the same as the ones used for NO<sub>x</sub> control diagnostics, or other maintenance purposes.

The visual element of the dual-fuel operating mode indicator shall not be the same as the one used for the purpose of NO<sub>x</sub> control diagnostics, or for other engine maintenance purposes.

Safety alerts always have display priority over the operating mode indication.

4.3.1.1. The dual-fuel mode indicator shall be set to service mode as soon as the service mode is activated (i.e. before it becomes actually active) and the indication shall remain as long as the service mode is active.

4.3.1.2. The dual-fuel mode indicator shall be set for at least one minute on dual-fuel mode or liquid-fuel mode as soon as the engine operating mode is changed from liquid fuel to dual-fuel mode or vice-versa. This indication is also required for at least one minute at key-on, or at the request of the manufacturer at engine cranking. The indication shall also be given upon the operator's request.

#### 4.3.2. Empty gaseous fuel tank warning system (dual-fuel warning system)

Non-road mobile machinery fitted with a dual-fuel engine shall be equipped with a dual-fuel warning system that alerts the operator that the gaseous fuel tank will soon become empty.

The dual-fuel warning system shall remain active until the tank is refuelled to a level above which the warning system is activated.

The dual-fuel warning system may be temporarily interrupted by other warning signals providing important safety-related messages.

It shall not be possible to turn off the dual-fuel warning system by means of a scan-tool as long as the cause of the warning activation has not been rectified.

##### 4.3.2.1. Characteristics of the dual-fuel warning system

The dual-fuel warning system shall consist of a visual alert system (icon, pictogram, etc.) left to the choice of the manufacturer.

It may include, at the choice of the manufacturer, an audible component. In that case, the cancelling of that component by the operator is permitted.

The visual element of the dual-fuel warning system shall not be the same as the one used for the purpose of NO<sub>x</sub> control diagnostics, or for other engine maintenance purposes.

In addition the dual-fuel warning system may display short messages, including messages indicating clearly the remaining distance or time before the activation of the operability restriction.

The system used for displaying the warning or messages referred to in this point may be the same as the one used for displaying the warning or messages related the NO<sub>x</sub> control diagnostics, or warning or messages for other maintenance purposes.

A facility to permit the operator to dim the visual alarms provided by the warning system may be provided on non-road mobile machinery for use by the rescue services or on non-road mobile machinery designed and constructed for use by the armed services, civil defense, fire services and forces responsible for maintaining public order.

#### 4.4. Communicated torque

##### 4.4.1. Communicated torque when a dual-fuel engine operates in dual-fuel mode

When a dual-fuel engine operates in dual-fuel mode:

- (a) The reference torque curve retrievable shall be the one obtained when that engine is tested on an engine test bench in the dual-fuel mode;
- (b) The recorded actual torques (indicated torque and friction torque) shall be the result of the dual-fuel combustion and not the one obtained when operating with liquid fuel exclusively.



#### 4.4.2. Communicated torque when a dual-fuel engine operates in liquid-fuel mode

When a dual-fuel engine operates in liquid-fuel mode, the reference torque curve retrievable shall be the one obtained when the engine is tested on an engine test bench in liquid-fuel mode.

#### 4.5. Additional requirements

4.5.1. Where used for a dual-fuel engine, adaptive strategies shall, in addition to satisfying the requirements of Annex IV, additionally comply with the following requirements:

- (a) The engine shall always remain within the dual-fuel engine type (that is Type 1A, Type 2B, etc.) that has been declared for EU type-approval; and
- (b) In case of a Type 2 engine, the resulting difference between the highest and the lowest maximum  $GER_{cycle}$  within the family shall never exceed the % specified in point 3.1.1., except as permitted by point 3.2.1..

4.6 The type approval shall be conditional upon providing to the OEM and end-users, as required by in accordance with Annexes XIV and XV, instructions for installation and operation of the dual-fuel engine including the service mode set out in point 4.2. and the dual-fuel indicator system set out in point 4.3..

#### 5. Performance requirements

5.1. The performance requirements, including emission limit values, and the requirements for EU type-approval applicable to dual-fuel engines are identical to those of any other engine of the respective engine category as set out in this Regulation and in Regulation (EU) 2016/1628, except as set out in this Annex.

5.2 The hydrocarbon (HC) limit for operation in dual-fuel mode shall be determined using the average gas energy ratio (GER) over the specified test cycle as set out in Annex II to Regulation (EU) 2016/1628.

5.3 The technical requirements on emission control strategies, including documentation required to demonstrate these strategies, technical provisions to resist tampering and the prohibition of defeat devices are identical to those of any other engine of the respective engine category as set out in Annex IV.

5.4 The detailed technical requirements on the area associated with the relevant NRSC, within which there is control of the amount that the emissions shall be permitted to exceed the limit values set out in Annex II to Regulation (EU) 2016/1628 are identical to those of any other engine of the respective engine category as set out in Annex IV.

#### 6. Demonstration requirements

6.1. The demonstration requirements applicable to dual-fuel engines are identical to those of any other engine of the respective engine category as set out in this Regulation and in Regulation (EU) 2016/1628, except as set out in section 6...

6.2. Compliance with the applicable limit values shall be demonstrated in dual-fuel mode.

- 6.3. For dual-fuel engine types with a liquid-fuel mode (i.e. types 1B, 2B, 3B) compliance with the applicable limit values shall additionally be demonstrated in liquid-fuel mode.
- 6.4. Additional demonstration requirements in case of a Type 2 engine
- 6.4.1 The manufacturer shall present the approval authority with evidence showing that the  $GER_{cycle}$  span of all members of the dual-fuel engine family remains within the % specified in point 3.1.1., or in the case of engines with an operator-adjustable  $GER_{cycle}$  satisfy the requirements of point 6.5. (for example, through algorithms, functional analyses, calculations, simulations, results of previous tests, etc.).
- 6.5 Additional demonstration requirements in case of an engine with an operator-adjustable  $GER_{cycle}$
- 6.5.1 Compliance with the applicable limit values shall be demonstrated at the minimum and maximum value of  $GER_{cycle}$  permitted by the manufacturer.
- 6.6. Requirements for demonstrating the durability of a dual-fuel engine
- 6.6.1 Provisions of Annex III shall apply.
- 6.7. Demonstration of the dual-fuel indicators, warning and operability restriction
- 6.7.1 As part of the application for EU type-approval under this Regulation, the manufacturer shall demonstrate the operation of dual-fuel indicators and of the warning and operability restriction in accordance with the provisions of Appendix 1.
7. Requirements to ensure the correct operation of  $NO_x$  control measures
- 7.1. Annex IV (technical requirements on  $NO_x$  control measures) shall apply to dual-fuel engines, whether operating in dual-fuel or liquid mode.
- 7.2. Additional  $NO_x$  control requirements in case of Type 1B, Type 2B and Type 3B dual-fuel engines
- 7.2.1. The torque considered to apply to the severe inducement defined in point 5.4. of Appendix 1 of Annex IV shall be the lowest of the torques obtained in liquid-fuel mode and in dual-fuel mode.
- 7.2.2 A possible influence of the mode of operation on the malfunction detection shall not be used to extend the time until an inducement becomes active.
- 7.2.3. In the case of malfunctions the detection of which does not depend on the operation mode of the engine, the mechanisms specified in Appendix 1 of Annex IV that are associated with the DTC status shall not depend on the operation mode of the engine (for example, if a DTC reached the potential status in dual-fuel mode, it will get the confirmed and active status the next time the failure is detected, even in liquid-fuel mode).
- 7.2.4. In the case of malfunctions where the detection depends on the operation mode of the engine, DTCs shall not get a previously active status in a different mode than the mode in which they reached the confirmed and active status.

7.2.5. A change of the mode of operation (dual-fuel to liquid fuel or vice-versa) shall not stop nor reset the mechanisms implemented to comply with the requirements set out in Annex IV (e.g. counters). However, in the case where one of these mechanisms (for example a diagnostic system) depends on the actual operation mode the counter associated with that mechanism may, at the request of the manufacturer and upon approval of the approval authority:

- (a) Halt and, when applicable, hold their present value when the operation mode changes;
- (b) Restart and, when applicable, continue counting from the point at which they have been held when the operation mode changes backs to the other operation mode.

## Appendix 1

### **Dual-fuel engine dual-fuel indicator, warning system, operability restriction - Demonstration requirements**

#### 1. Dual-fuel indicators

##### 1.1. Dual-fuel mode indicator

The ability of the engine to command the activation of the dual-fuel mode indicator when operating in dual-fuel mode shall be demonstrated at EU type-approval.

##### 1.2. Liquid-fuel mode indicator

In the case of a Type 1B, Type 2B, or Type 3B dual-fuel engine the ability of the engine to command the activation of the liquid-fuel mode indicator when operating in liquid-fuel mode shall be demonstrated at EU type-approval.

##### 1.3. Service mode indicator

The ability of the engine to command the activation of the service mode indicator when operating in service mode shall be demonstrated at EU type-approval.

- 1.3.1. When so-equipped it is sufficient to perform the demonstration related to the service mode indicator by activating a service mode activation switch and to present the approval authority with evidence showing that the activation occurs when the service mode is commanded by the engine system itself (for example, through algorithms, simulations, result of in-house tests, etc. ...).

#### 2. Warning system

The ability of the engine to command the activation of the warning system in the case that the amount of gaseous fuel in the gaseous fuel tank is below the warning level, shall be demonstrated at EU type-approval. For that purpose the actual amount of gaseous fuel may be simulated.

#### 3. Operability restriction

In the case of a Type 1A or Type 2A dual-fuel engine the ability of the engine to command the activation of the operability restriction upon detection of an empty gaseous fuel tank and of a malfunctioning gas supply system shall be demonstrated at EU type-approval. For that purpose the empty gaseous fuel tank and the malfunctioning of the gas supply may be simulated.

- 3.1. It is sufficient to perform the demonstration in a typical use-case selected with the agreement of the approval authority and to present that authority with evidence showing that the operability restriction occurs in the other possible use-cases (for example, through algorithms, simulations, result of in-house tests, etc).

## Appendix 2

### Emission test procedure requirements for dual-fuel engines

#### 1. General

This point defines the additional requirements and exceptions of this Annex to enable emission testing of dual-fuel engines independent whether these emissions are solely exhaust emissions or also crankcase emissions added to the exhaust emissions according to point 6.10. of Annex VI. In the case that no additional requirement or exception is listed, the requirements of this Regulation shall apply to dual-fuel engines in the same way as they apply to any other approved engine types or engine families under Regulation (EU) 2016/1628.

Emission testing of a dual-fuel engine is complicated by the fact that the fuel used by the engine can vary between pure liquid fuel and a combination of mainly gaseous fuel with only a small amount of liquid fuel as an ignition source. The ratio between the fuels used by a dual-fuel engine can also change dynamically depending of the operating condition of the engine. As a result special precautions and restrictions are necessary to enable emission testing of these engines.

#### 2. Test conditions

Section 6. of Annex VI shall apply.

#### 3. Test procedures

Section 7. of Annex VI shall apply.

#### 4. Measurement procedures

Section 8. of Annex VI shall apply except as set out in this Appendix.

A full-flow dilution measurement procedure for dual-fuel engines is illustrated in Figure 6.6. of Annex VI (CVS system).

This measurement procedure ensures that the variation of the fuel composition during the test will mainly influence the hydrocarbon measurement results. This shall be compensated via one of the methods described in point 5.1..

Raw gaseous/partial flow measurement illustrated in Figure 6.7. of Annex VI may be used with some precautions regarding exhaust gas mass flow determination and calculation methods.

#### 5. Measurement equipment

Section 9. of Annex VI shall apply.

#### 6. Particle number emissions measurement

Appendix 1 of Annex VI shall apply.

## 7. Emission calculation

The emission calculation shall be performed according to Annex VII except as set out in this section. The additional requirements set out in point 7.1. shall apply for mass-based calculations and the additional requirements set out in point 7.2. shall apply for molar-based calculations.

The emission calculation requires knowledge of the composition of the fuels being used. When a gaseous fuel is supplied with a certificate confirming the properties of the fuel (e.g. gas from bottles) it is acceptable to use the composition specified by the supplier. Where the composition is not available (e.g. pipeline fuel) the fuel composition shall be analysed at least prior to and after the engine emission test is conducted. More frequent analysis shall be permitted and the results used in the calculation.

Where the gas energy ratio (GER) is used it shall be consistent with the definition in Article 3(2) of Regulation (EU) 2016/1628 and the specific provisions on total hydrocarbon (HC) limits for fully and partially gaseous-fuelled engines in Annex II of that Regulation. The average value of GER over the cycle shall be calculated by one of the following methods:

- (a) For hot-start NRTC and RMC NRSC by dividing the sum of the GER at each measurement point by the number of measurement points;
- (b) For discrete-mode NRSC by multiplying the average GER for each test mode by the corresponding weighting factor for that mode and calculating the sum for all modes. The weighting factors shall be taken from Appendix 1 of Annex XVII for the applicable cycle.

### 7.1. Mass-based emission calculation

Section 2. of Annex VII shall apply except as set out in this section.

#### 7.1.1. Dry/wet correction

##### 7.1.1.1. Raw exhaust gas

Equations (7-3) and (7-4) of Annex VII shall be used to calculate the dry/wet correction.

The fuel specific parameters shall be determined in accordance with point 7.1.5..

##### 7.1.1.2. Diluted exhaust gas

Equation (7-3) with either equation (7-25) or (7-26) of Annex VII shall be used to calculate the wet/dry correction.

The molar hydrogen ratio  $\alpha$  of the combination of the two fuels shall be used for the dry/wet correction. This molar hydrogen ratio shall be calculated from the fuel consumption measurement values of both fuels in accordance with point 7.1.5..

#### 7.1.2. NO<sub>x</sub> correction for humidity

The NO<sub>x</sub> humidity correction for compression ignition engines as specified in equation (7-9) of Annex VII shall be used.

### 7.1.3. Partial flow dilution (PFS) and raw gaseous measurement

#### 7.1.3.1. Determination of exhaust gas mass flow

The exhaust gas mass flow shall be determined using a raw exhaust flow meter as described in point 9.4.5.3. of Annex VI.

Alternatively the airflow and air to fuel ratio measurement method according to equations (7-17) to (7-19) of Annex VII may be used only if  $\alpha$ ,  $\gamma$ ,  $\delta$  and  $\varepsilon$  values are determined according to point 7.1.5.3.. The use of a zirconia-type sensor to determine the air fuel ratio is not allowed.

In the case of testing engines subject to steady-state test cycles only the exhaust gas mass flow may be determined by the air and fuel measurement method in accordance with equation (7-15) of Annex VII.

#### 7.1.3.2. Determination of the gaseous components

Point 2.1. of Annex VII shall apply except as set out in this section.

The possible variation of fuel composition will influence all the  $u_{gas}$  factors and molar component ratios used in the emission calculations. One of the following approaches shall be used to determine  $u_{gas}$  factors and molar component ratios at the choice of the manufacturer.

- (a) The exact equations in point 2.1.5.2. or 2.2.3. of Annex VII shall be applied to calculate instantaneous values of  $u_{gas}$  using the instantaneous proportions of liquid and gaseous fuel (determined from instantaneous fuel consumption measurements or calculations) and instantaneous molar component ratios determined in accordance with point 7.1.5.; or,
- (b) When the mass-based calculation in section 2. of Annex VII is used for the specific case of a dual-fuel engine operated on gas and diesel fuel, tabulated values may be used for the molar component ratios and  $u_{gas}$  values. These tabulated values shall be applied as follows:
  - i. For engines operated on the applicable test cycle with an average gas energy ratio greater than or equal to 90 % ( $GER \geq 0,9$ ) the required values shall be those for the gaseous fuel taken from Tables 7.1. or 7.2. of Annex VII.
  - ii. For engines operated on the applicable test cycle with an average gas energy ratio between 10 % and 90 % ( $0,1 < GER < 0,9$ ) the required values shall be assumed to be represented by those for a mixture of 50 % gaseous fuel and 50 % diesel fuel taken from Tables 8.1. and 8.2..
  - iii. For engines operated on the applicable test cycle with an average gas energy ratio less than or equal to 10 % ( $GER \leq 0,1$ ) the required values shall be those for diesel fuel taken from taken from Tables 7.1. or 7.2. of Annex VII.

- iv. For the calculation of HC emissions the  $u_{gas}$  value of the gaseous fuel shall be used in all cases irrespective of the average gas energy ratio (GER).

*Table 8.1.*  
**Molar component ratios for a mixture of 50 % gaseous fuel and 50 % diesel fuel (mass %)**

Gaseous fuel	$\alpha$	$\gamma$	$\delta$	$\varepsilon$
CH <sub>4</sub>	2,8681	0	0	0,0040
G <sub>R</sub>	2,7676	0	0	0,0040
G <sub>23</sub>	2,7986	0	0,0703	0,0043
G <sub>25</sub>	2,7377	0	0,1319	0,0045
Propane	2,2633	0	0	0,0039
Butane	2,1837	0	0	0,0038
LPG	2,1957	0	0	0,0038
LPG Fuel A	2,1740	0	0	0,0038
LPG Fuel B	2,2402	0	0	0,0039

#### 7.1.3.2.1. Mass per test of a gaseous emission

In the case that the exact equations are applied to calculate instantaneous values of  $u_{gas}$  in accordance with paragraph 7.1.3.2.1(a) then, when calculating the mass per test of a gaseous emission for transient (NRTC and LSI-NRTC) test cycles and RMC,  $u_{gas}$  shall be included in the summation in equation (7-2) of point 2.1.2 of Annex VII by means of equation (8-1):

$$m_{gas} = \frac{1}{f} \cdot k_h \cdot k \cdot \sum_{i=1}^N (u_{gas,i} \cdot q_{mew,i} \cdot c_{gas,i}) \quad (8-1)$$

Where:

$u_{gas,i}$  is the instantaneous value of  $u_{gas}$

The remaining terms of the equation are as set out in point 2.1.2 of Annex VII.

*Table 8.2.*  
**Raw exhaust gas  $u_{gas}$  values and component densities for a mixture of 50% gaseous fuel and 50% diesel fuel (mass %)**



Gaseous fuel	Gas						
		NO <sub>x</sub>	CO	HC	CO <sub>2</sub>	O <sub>2</sub>	CH <sub>4</sub>
	$\rho_e$	$\rho_{\text{gas}}$ [kg/m <sup>3</sup> ]					
		2,053	1,250	(a)	1,9636	1,4277	0,716
	$u_{\text{gas}}$ <sup>(b)</sup>						
<b>CNG/LNG<sup>(e)</sup></b>	1,2786	0,001606	0,000978	0,000528 <sup>(c)</sup>	0,001536	0,001117	0,000560
<b>Propane</b>	1,2869	0,001596	0,000972	0,000510	0,001527	0,001110	0,000556
<b>Butane</b>	1,2883	0,001594	0,000971	0,000503	0,001525	0,001109	0,000556
<b>LPG<sup>(e)</sup></b>	1,2881	0,001594	0,000971	0,000506	0,001525	0,001109	0,000556
(a) depending on fuel							
(b) at $\lambda = 2$ , dry air, 273 K, 101,3 kPa							
(c) $u$ accurate within 0,2 % for mass composition of: C = 58 - 76 %; H = 19 - 25 %; N = 0 - 14 % (CH <sub>4</sub> , G <sub>20</sub> , G <sub>23</sub> , and G <sub>25</sub> )							
(d) NMHC on the basis of CH <sub>2,93</sub> (for total HC the $u_{\text{gas}}$ coefficient of CH <sub>4</sub> shall be used)							
(e) $u$ accurate within 0,2 % for mass composition of: C <sub>3</sub> = 27 - 90 %; C <sub>4</sub> = 10 - 73 % (LPG Fuels A and B)							

### 7.1.3.3. Particulate determination

For the determination of particulate emissions with the partial dilution measurement method the calculation shall be performed according to the equations in point 2.3. of Annex VII.

The requirements of point 8.2.1.2. of Annex VI shall apply for controlling the dilution ratio. In particular, if the combined transformation time of the exhaust gas flow measurement and the partial flow system exceeds 0 s, look-ahead control based on a pre-recorded test run shall be used. In this case, the combined rise time shall be  $\leq 1$  s and the combined delay time  $\leq 10$  s. Except in the case that the exhaust gas mass flow is measured directly the determination of exhaust gas mass flow shall use values of  $\alpha$ ,  $\gamma$ ,  $\delta$  and  $\varepsilon$  determined according to point 7.1.5.3..

The quality check according to point 8.2.1.2. of Annex VI shall be performed for each measurement.

### 7.1.3.4. Additional requirements regarding the exhaust gas mass flow meter

The flow meter referred to in points 9.4.1.6.3. and 9.4.1.6.3.3. of Annex VI shall not be sensitive to the changes in exhaust gas composition and density. The small errors of e.g. pitot tube or orifice-type of measurement (equivalent with the square root of the exhaust gas density) may be neglected.

#### 7.1.4. Full flow dilution measurement (CVS)

Point 2.2. of Annex VII shall apply except as set out in this section.

The possible variation of the fuel composition will mainly influence the tabulated hydrocarbon  $u_{gas}$  value. The exact equations shall be applied for the calculation of the hydrocarbon emissions using the molar component ratios determined from the fuel consumption measurements of both fuels according to point 7.1.5..

##### 7.1.4.1. Determination of the background corrected concentrations (point 5.2.5.)

To determine the stoichiometric factor, the molar hydrogen ratio  $\alpha$  of the fuel shall be calculated as the average molar hydrogen ratio of the fuel mix during the test according to point 7.1.5.3..

Alternatively the  $F_s$  value of the gaseous fuel may be used in equation (7-28) of Annex VII.

#### 7.1.5. Determination of molar component ratios

##### 7.1.5.1. General

This section shall be used for the determination of molar component ratios when the fuel mix is known (exact method).

##### 7.1.5.2. Calculation of the fuel mixture components

Equations (8-2) to (8-7) shall be used to calculate the elemental composition of the fuel mixture:

$$q_{mf} = q_{mf1} + q_{mf2} \quad (8-2)$$

$$W_H = \frac{w_{H1} \times q_{mf1} + w_{H2} \times q_{mf2}}{q_{mf1} + q_{mf2}} \quad (8-3)$$

$$W_C = \frac{w_{C1} \times q_{mf1} + w_{C2} \times q_{mf2}}{q_{mf1} + q_{mf2}} \quad (8-4)$$

$$W_S = \frac{w_{S1} \times q_{mf1} + w_{S2} \times q_{mf2}}{q_{mf1} + q_{mf2}} \quad (8-5)$$

$$W_N = \frac{w_{N1} \times q_{mf1} + w_{N2} \times q_{mf2}}{q_{mf1} + q_{mf2}} \quad (8-6)$$

$$W_O = \frac{w_{O1} \times q_{mf1} + w_{O2} \times q_{mf2}}{q_{mf1} + q_{mf2}} \quad (8-7)$$

where:

$q_{mf1}$  is the fuel mass flow rate of fuel 1, kg/s

$q_{mf2}$  is the fuel mass flow rate of fuel 2, kg/s

$w_H$	is the hydrogen content of fuel, % mass
$w_C$	is the carbon content of fuel, % mass
$w_S$	is the sulphur content of fuel, % mass
$w_N$	is the nitrogen content of fuel, % mass
$w_O$	is the oxygen content of fuel, % mass

Calculation of the molar ratios of H, C, S, N and O related to C for the fuel mixture

The calculation of the atomic ratios (especially the H/C-ratio  $\alpha$ ) is given in Annex VII by means of equations (8-8) to (8-11):

$$\alpha = 11.9164 \cdot \frac{w_H}{w_C} \quad (8-8)$$

$$\gamma = 0.37464 \cdot \frac{w_S}{w_C} \quad (8-9)$$

$$\delta = 0.85752 \cdot \frac{w_N}{w_C} \quad (8-10)$$

$$\varepsilon = 0.75072 \cdot \frac{w_O}{w_C} \quad (8-11)$$

where:

$w_H$  is the hydrogen content of fuel, mass fraction [g/g] or [per cent mass]

$w_C$  is the carbon content of fuel, mass fraction [g/g] or [per cent mass]

$w_S$  is the sulphur content of fuel, mass fraction [g/g] or [per cent mass]

$w_N$  is the nitrogen content of fuel, mass fraction [g/g] or [per cent mass]

$w_O$  is the oxygen content of fuel, mass fraction [g/g] or [per cent mass]

$\alpha$  is the molar hydrogen ratio (H/C)

$\gamma$  is the molar sulphur ratio (S/C)

$\delta$  is the molar nitrogen ratio (N/C)

$\varepsilon$  is the molar oxygen ratio (O/C)

referring to a fuel  $CH_\alpha O_\varepsilon N_\delta S_\gamma$

## 7.2. Molar-based emission calculation

Annex VII section 3. shall apply except as set out in this section.

### 7.2.1. $NO_x$ correction for humidity

Equation (7-102) of Annex VII (correction for compression ignition engines) shall be used.

### 7.2.2. Determination of exhaust gas mass flow when not using a raw exhaust flow meter

Equation (7-112) of Annex VII (molar flow rate calculation based on intake air) shall be used. Equation (7-113) of Annex VII (molar flow rate calculation based on fuel mass flow rate) may alternatively be used only when conducting an NRSC test.

### 7.2.3. Molar component ratios for determination of the gaseous components

The exact approach shall be used to determine the molar component ratios using the instantaneous proportions of liquid and gaseous fuel determined from instantaneous fuel consumption measurements or calculations. The instantaneous molar component ratios shall be input in the equations (7-91), (7-89), and (7-94) of Annex VII for the continuous chemical balance.

The determination of the ratios shall be either performed according to point 7.2.3.1. or point 7.1.5.3..

Gaseous fuels, either blended or sourced from a land line, may contain significant amounts of inert constituents such as CO<sub>2</sub> and N<sub>2</sub>. The manufacturer shall either include these constituents in the atomic ratio calculations described in point 7.2.3.1. or point 7.1.5.3. as applicable, or, alternatively, the manufacturer shall exclude the inert constituents from the atomic ratios and allocate them appropriately to the chemical balance intake air parameters  $x_{O_2int}$ ,  $x_{CO_2int}$ , and  $x_{H_2Oint}$  in point 3.4.3. of Annex VII.

#### 7.2.3.1. Determination of molar component ratios

Instantaneous molar component ratios of the number of hydrogen, oxygen, sulphur, and nitrogen atoms to carbons atoms in the mixed fuel for the dual-fuel engines may be calculated by means of equations (8-12) to (8-15):

$$\alpha(t) = \frac{\frac{\dot{m}_{liquid}(t) \times w_{H,liquid}}{M_H} + \frac{\dot{m}_{gas}(t) \times w_{H,gas}}{M_H}}{\frac{\dot{m}_{liquid}(t) \times w_{C,liquid}}{M_C} + \frac{\dot{m}_{gas}(t) \times w_{C,gas}}{M_C}} = \frac{M_C \times [(\dot{m}_{liquid}(t) \times w_{H,liquid}) + (\dot{m}_{gas}(t) \times w_{H,gas})]}{M_H \times [(\dot{m}_{liquid}(t) \times w_{C,liquid}) + (\dot{m}_{gas}(t) \times w_{C,gas})]} \quad (8-12)$$

$$\beta(t) = \frac{\frac{\dot{m}_{liquid}(t) \times w_{O,liquid}}{M_O} + \frac{\dot{m}_{gas}(t) \times w_{O,gas}}{M_O}}{\frac{\dot{m}_{liquid}(t) \times w_{C,liquid}}{M_C} + \frac{\dot{m}_{gas}(t) \times w_{C,gas}}{M_C}} = \frac{M_C \times [(\dot{m}_{liquid}(t) \times w_{O,liquid}) + (\dot{m}_{gas}(t) \times w_{O,gas})]}{M_O \times [(\dot{m}_{liquid}(t) \times w_{C,liquid}) + (\dot{m}_{gas}(t) \times w_{C,gas})]} \quad (8-13)$$

$$\gamma(t) = \frac{\frac{\dot{m}_{liquid}(t) \times w_{S,liquid}}{M_S} + \frac{\dot{m}_{gas}(t) \times w_{S,gas}}{M_S}}{\frac{\dot{m}_{liquid}(t) \times w_{C,liquid}}{M_C} + \frac{\dot{m}_{gas}(t) \times w_{C,gas}}{M_C}} = \frac{M_C \times [(\dot{m}_{liquid}(t) \times w_{S,liquid}) + (\dot{m}_{gas}(t) \times w_{S,gas})]}{M_S \times [(\dot{m}_{liquid}(t) \times w_{C,liquid}) + (\dot{m}_{gas}(t) \times w_{C,gas})]} \quad (8-14)$$

$$\delta(t) = \frac{\frac{\dot{m}_{liquid}(t) \times w_{N,liquid}}{M_N} + \frac{\dot{m}_{gas}(t) \times w_{N,gas}}{M_N}}{\frac{\dot{m}_{liquid}(t) \times w_{C,liquid}}{M_C} + \frac{\dot{m}_{gas}(t) \times w_{C,gas}}{M_C}} = \frac{M_C \times [(\dot{m}_{liquid}(t) \times w_{N,liquid}) + (\dot{m}_{gas}(t) \times w_{N,gas})]}{M_N \times [(\dot{m}_{liquid}(t) \times w_{C,liquid}) + (\dot{m}_{gas}(t) \times w_{C,gas})]} \quad (8-15)$$

Where:

- $w_{i,fuel}$  = the mass fraction of the element of interest, C, H, O, S, or N, of liquid or gaseous fuel;
- $\dot{m}_{liquid}(t)$  = the instantaneous mass flow rate of the liquid fuel at time t, [kg/hr];
- $\dot{m}_{gas}(t)$  = the instantaneous mass flow rate of the gaseous fuel at time t, [kg/hr];

In cases where exhaust gas mass flow rate is calculated based on the mixed fuel rate then  $w_C$  in equation (7-111) of Annex VII shall be calculated by means of equation (8-16):

$$w_C = \frac{\dot{m}_{liquid} \times w_{C,liquid} + \dot{m}_{gas} \times w_{C,gas}}{\dot{m}_{liquid} + \dot{m}_{gas}} \quad (8-16)$$

Where:

- $w_C$  = the mass fraction of the carbon in the diesel or gaseous fuel;
- $\dot{m}_{liquid}$  = the mass flow rate of the liquid fuel, [kg/hr];
- $\dot{m}_{gas}$  = the mass flow rate of the gaseous fuel, [kg/hr].

### 7.3. CO<sub>2</sub> determination

Annex VII shall apply except when the engine is tested on transient (NRTC and LSI-NRTC) test cycles or RMC using raw gas sampling.

#### 7.3.1 CO<sub>2</sub> determination when testing on transient (NRTC and LSI-NRTC) test cycles or RMC using raw gas sampling

Calculation of CO<sub>2</sub> emissions from measurement of CO<sub>2</sub> in the exhaust gas in accordance with Annex VII shall not apply. Instead the following provisions shall apply:

The measured test-averaged fuel consumption shall be determined from the sum of the instantaneous values over the cycle and shall be used as the base for calculating the test averaged CO<sub>2</sub> emissions.

The mass of each fuel consumed shall be used to determine, in accordance with section 7.1.5, the molar hydrogen ratio and the mass fractions of the fuel mix in the test.

The total corrected fuel mass of both fuels  $m_{fuel,corr}$  [g/test] and CO<sub>2</sub> mass emission coming from the fuel  $m_{CO_2, fuel}$  [g/test] shall be determined by means of equations (8-17) and (8-18).

$$m_{fuel,corr} = m_{fuel} - \left( m_{THC} + \frac{A_C + a \cdot A_H}{M_{CO}} x m_{CO} + \frac{W_{GAM} + W_{DEL} + W_{EPS}}{100} * m_{fuel} \right) \quad (8-17)$$

$$m_{CO_2, fuel} = \frac{M_{CO_2}}{A_C + a \cdot A_H} * m_{fuel,corr} \quad (8-18)$$

Where:

$m_{\text{fuel}}$  = total fuel mass of both fuels [g/test]

$m_{\text{THC}}$  = mass of total hydrocarbon emissions in the exhaust gas [g/test]

$m_{\text{CO}}$  = mass of carbon monoxide emissions in the exhaust gas [g/test]

$w_{\text{GAM}}$  = sulphur content of the fuels [per cent mass]

$w_{\text{DEL}}$  = nitrogen content of the fuels [per cent mass]

$w_{\text{EPS}}$  = is the oxygen content of the fuels [per cent mass]

$\alpha$  = is the molar hydrogen ratio of the fuels (H/C) [-]

$A_{\text{C}}$  = is the atomic mass of Carbon: 12.011 [g/mol]

$A_{\text{H}}$  = is the atomic mass of Hydrogen: 1.0079 [g/mol]

$M_{\text{CO}}$  = is the molecular mass of Carbon monoxide: 28.011 [g/mol]

$M_{\text{CO}_2}$  = is the molecular mass of Carbon dioxide: 44.01 [g/mol]

The CO<sub>2</sub> emission resulting from urea  $m_{\text{CO}_2,\text{urea}}$  [g/test] shall be calculated by means of equation (8-19):

$$m_{\text{CO}_2,\text{urea}} = \frac{c_{\text{urea}}}{100} \times \frac{M_{\text{CO}_2}}{M_{\text{CO}(\text{NH}_2)_2}} \times m_{\text{urea}} \quad (8-19)$$

Where:

$c_{\text{urea}}$  = urea concentration [per cent]

$m_{\text{urea}}$  = total urea mass consumption [g/test]

$M_{\text{CO}(\text{NH}_2)_2}$  = Molecular mass of urea: 60,056 [g/mol]

Then the total CO<sub>2</sub> emission  $m_{\text{CO}_2}$  [g/test] shall be calculated by means of equation (8-20):

$$m_{\text{CO}_2} = m_{\text{CO}_2,\text{fuel}} + m_{\text{CO}_2,\text{urea}} \quad (8-20)$$

The total CO<sub>2</sub> emission calculated by means of equation (8-20) shall be used in the calculation of brake specific CO<sub>2</sub> emissions,  $e_{\text{CO}_2}$  [g/kWh] in section 2.4.1.1 or 3.8.1.1 of Annex VII. Where applicable, the correction for CO<sub>2</sub> in the exhaust gas arising from CO<sub>2</sub> in the gaseous fuel shall be performed in accordance with Appendix 3 to Annex IX.

### Appendix 3

#### **Types of dual-fuel engines operated on natural gas/biomethane or LPG and a liquid fuel** **– illustration of the definitions and main requirements**

Dual-fuel type	$GER_{cycle}$	Idle on liquid fuel	Warm-up on liquid fuel	Operation on liquid fuel solely	Operation in absence of gas	Comments
1A	$GER_{NRTC, hot} \geq 0,9$ or $GER_{NRSC} \geq 0,9$	NOT allowed	Allowed only on service mode	Allowed only on service mode	Service mode	
1B	$GER_{NRTC, hot} \geq 0,9$ or $GER_{NRSC} \geq 0,9$	Allowed only on liquid-fuel mode	Allowed only on liquid-fuel mode	Allowed only on liquid-fuel and service modes	Liquid-fuel mode	
2A	$0,1 < GER_{NRTC, hot} < 0,9$ or $0,1 < GER_{NRSC} < 0,9$	Allowed	Allowed only on service mode	Allowed only on service mode	Service mode	$GER_{NRTC, hot} \geq 0,9$ or $GER_{NRSC} \geq 0,9$ Allowed
2B	$0,1 < GER_{NRTC, hot} < 0,9$ or $0,1 < GER_{NRSC} < 0,9$	Allowed	Allowed	Allowed	Liquid-fuel mode	$GER_{NRTC, hot} \geq 0,9$ or $GER_{NRSC} \geq 0,9$ allowed
3A	Neither defined nor allowed					
3B	$GER_{NRTC, hot} \leq 0,1$ or $GER_{NRSC} \leq 0,1$	Allowed	Allowed	Allowed	Liquid-fuel mode	

## ANNEX IX

### Reference Fuels

#### 1. Technical data on fuels for testing compression-ignition engines

##### 1.1. Type: Diesel (non-road gas-oil)

<i>Parameter</i>	<i>Unit</i>	<i>Limits<sup>1</sup></i>		<i>Test Method</i>
		<i>minimum</i>	<i>maximum</i>	
Cetane number <sup>2</sup>		45	56,0	EN-ISO 5165
Density at 15 °C	kg/m <sup>3</sup>	833	865	EN-ISO 3675
Distillation:				
50 % point	°C	245	-	EN-ISO 3405
95 % point	°C	345	350	EN-ISO 3405
- Final boiling point	°C	-	370	EN-ISO 3405
Flash point	°C	55	-	EN 22719
CFPP	°C	-	-5	EN 116
Viscosity at 40 °C	mm <sup>2</sup> /s	2,3	3,3	EN-ISO 3104
Polycyclic aromatic hydrocarbons	% m/m	2,0	6,0	IP 391
Sulphur content <sup>3</sup>	mg/kg	-	10	ASTM D 5453
Copper corrosion		-	class 1	EN-ISO 2160
Conradson carbon residue (10 % DR)	% m/m	-	0,2	EN-ISO 10370
Ash content	% m/m	-	0,01	EN-ISO 6245
Total contamination	mg/kg	-	24	EN 12662
Water content	% m/m	-	0,02	EN-ISO 12937
Neutralization (strong acid) number	mg KOH/g	-	0,10	ASTM D 974
Oxidation stability <sup>3</sup>	mg/ml	-	0,025	EN-ISO 12205
Lubricity (HFRR wear scar diameter at 60 °C)	µm	-	400	CEC F-06-A-96
Oxidation stability at 110 °C <sup>3</sup>	H	20,0	-	EN 15751
FAME	% v/v	-	7,0	EN 14078



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<sup>1</sup> The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 "Petroleum products – Determination and application of precision data in relation to methods of test" have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility).

Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels should nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify the questions as to whether a fuel meets the requirements of the specifications, the terms of ISO 4259 should be applied.

<sup>2</sup> The range for the cetane number is not in accordance with the requirements of a minimum range of 4R. However, in the case of a dispute between fuel supplier and fuel user, the terms of ISO 4259 may be used to resolve such disputes provided replicate measurements, of sufficient number to archive the necessary precision, are made in preference to single determinations.

<sup>3</sup> Even though oxidation stability is controlled, it is likely that shelf life will be limited. Advice should be sought from the supplier as to storage conditions and life.

1.2. Type: Ethanol for dedicated compression ignition engines (ED95)1

Parameter	Unit	Limits <sup>2</sup>		Test method <sup>3</sup>
		Minimum	Maximum	
Total alcohol (Ethanol incl. content on higher saturated alcohols)	% m/m	92,4		EN 15721
Other higher saturated mono-alcohols (C <sub>3</sub> -C <sub>5</sub> )	% m/m		2,0	EN 15721
Methanol	% m/m		0,3	EN 15721
Density 15°C	kg/m <sup>3</sup>	793,0	815,0	EN ISO 12185
Acidity, calculated as acetic acid	% m/m		0,0025	EN 15491
Appearance		Bright and clear		
Flashpoint	°C	10		EN 3679
Dry residue	mg/kg		15	EN 15691
Water content	% m/m		6,5	EN 15489 <sup>4</sup> EN-ISO 12937 EN15692
Aldehydes calculated as acetaldehyde	% m/m		0,0050	ISO 1388-4
Esters calculated as ethylacetat	% m/m		0,1	ASTM D1617
Sulphur content	mg/kg		10,0	EN 15485 EN 15486
Sulphates	mg/kg		4,0	EN 15492
Particulate contamination	mg/kg		24	EN 12662
Phosphorus	mg/l		0,20	EN 15487
Inorganic chloride	mg/kg		1,0	EN 15484 or EN 15492
Copper	mg/kg		0,100	EN 15488
Electrical Conductivity	µS/cm		2,50	DIN 51627-4 or prEN 15938

Notes:

- 1 Additives, such as cetane improver as specified by the engine manufacturer, may be added to the ethanol fuel, as long as no negative side effects are known. If these conditions are satisfied, the maximum allowed amount is 10 % m/m.
- 2 The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 Petroleum products – Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.
- 3 Equivalent EN/ISO methods will be adopted when issued for properties listed above.
- 4 Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of EN 15489 shall be applied.

## 2. Technical data on fuels for testing spark ignition engines

### 2.1. Type: Petrol (E10)

Parameter	Unit	Limits <sup>1</sup>		Test method <sup>2</sup>
		Minimum	Maximum	
Research octane number, RON		91,0	98,0	EN ISO 5164:2005 <sup>3</sup>
Motor octane number, MON		83,0	89,0	EN ISO 5163:2005 <sup>3</sup>
Density at 15 °C	kg/m <sup>3</sup>	743	756	EN ISO 3675 EN ISO 12185
Vapour pressure	kPa	45,0	60,0	EN ISO 13016-1 (DVPE)
Water content			Max 0,05 % v/v Appearance at -7°C: clear and bright	EN 12937
Distillation:				
- evaporated at 70 °C	% v/v	18,0	46,0	EN-ISO 3405
- evaporated at 100 °C	% v/v	46,0	62,0	EN-ISO 3405
- evaporated at 150 °C	% v/v	75,0	94,0	EN-ISO 3405
- final boiling point	°C	170	210	EN-ISO 3405
Residue	% v/v	—	2,0	EN-ISO 3405
Hydrocarbon analysis:				
- olefins	% v/v	3,0	18,0	EN 14517 EN 15553
- aromatics	% v/v	19,5	35,0	EN 14517 EN 15553
- benzene	% v/v	—	1,0	EN 12177 EN 238, EN 14517
- saturates	% v/v	Report		EN 14517 EN 15553
Carbon/hydrogen ratio		Report		
Carbon/oxygen ratio		Report		
Induction period <sup>4</sup>	minutes	480		EN-ISO 7536
Oxygen content <sup>5</sup>	% m/m	3,3 <sup>8</sup>	3,7	EN 1601 EN 13132 EN 14517
Existent gum	mg/ml	—	0,04	EN-ISO 6246
Sulphur content <sup>6</sup>	mg/kg	—	10	EN ISO 20846 EN ISO 20884
Copper corrosion (3h at 50 °C)	rating	—	Class 1	EN-ISO 2160
Lead content	mg/l	—	5	EN 237
Phosphorus content <sup>7</sup>	mg/l	—	1,3	ASTM D 3231
Ethanol <sup>4</sup>	% v/v	9,0 <sup>8</sup>	10,2 <sup>8</sup>	EN 22854

*Notes:*

- <sup>1</sup> The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 Petroleum products - Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.
- <sup>2</sup> Equivalent EN/ISO methods will be adopted when issued for properties listed above.
- <sup>3</sup> A correction factor of 0,2 for MON and RON shall be subtracted for the calculation of the final result in accordance with EN 228:2008.
- <sup>4</sup> The fuel may contain oxidation inhibitors and metal deactivators normally used to stabilise refinery gasoline streams, but detergent/dispersive additives and solvent oils shall not be added.
- <sup>5</sup> Ethanol meeting the specification of EN 15376 is the only oxygenate that shall be intentionally added to the reference fuel.
- <sup>6</sup> The actual sulphur content of the fuel used for the Type 1 test shall be reported.
- <sup>7</sup> There shall be no intentional addition of compounds containing phosphorus, iron, manganese, or lead to this reference fuel.
- <sup>8</sup> The ethanol content and corresponding oxygen content may be zero for engines of category SMB at the choice of the manufacturer. In this case all testing of the engine family, or engine type where no family exists, shall be conducted using petrol with zero ethanol content.

2.2. Type: Ethanol (E85)

Parameter	Unit	Limits <sup>1</sup>		Test method
		Minimum	Maximum	
Research octane number, RON		95,0	—	EN ISO 5164
Motor octane number, MON		85,0	—	EN ISO 5163
Density at 15 °C	kg/m <sup>3</sup>	Report		ISO 3675
Vapour pressure	kPa	40,0	60,0	EN ISO 13016-1 (DVPE)
Sulphur content <sup>2</sup>	mg/kg	—	10	EN 15485 or EN 15486
Oxidation stability	Minutes	360		EN ISO 7536
Existent gum content (solvent washed)	mg/100ml	—	5	EN-ISO 6246
Appearance This shall be determined at ambient temperature or 15°C whichever is higher		Clear and bright, visibly free of suspended or precipitated contaminants		Visual inspection
Ethanol and higher alcohols <sup>3</sup>	% v/v	83	85	EN 1601 EN 13132 EN 14517 E DIN 51627-3
Higher alcohols (C <sub>3</sub> -C <sub>8</sub> )	% v/v	—	2,0	E DIN 51627-3
Methanol	% v/v		1,00	E DIN 51627-3
Petrol <sup>4</sup>	% v/v	Balance		EN 228
Phosphous	mg/l	0,20 <sup>5</sup>		EN 15487
Water content	% v/v		0,300	EN 15489 or EN 15692
Inorganic chloride content	mg/l		1	EN 15492
pHe		6,5	9,0	EN 15490
Copper strip corrosion (3h at 50°C)	Rating	Class 1		EN ISO 2160
Acidity, (as acetic acid CH <sub>3</sub> COOH)	% m/m (mg/l)	—	0,0050 (40)	EN 15491
Electric Conductivity	µS/cm	1,5		DIN 51627-4 or prEN 15938
Carbon/hydrogen ratio		Report		
Carbon/oxygen ration		Report		

*Notes:*

- 1 The values quoted in the specifications are "true values". In establishment of their limit values the terms of ISO 4259 Petroleum products - Determination and application of precision data in relation to methods of test have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account; in fixing a maximum and minimum value, the minimum difference is 4R (R = reproducibility). Notwithstanding this measure, which is necessary for technical reasons, the manufacturer of fuels shall nevertheless aim at a zero value where the stipulated maximum value is 2R and at the mean value in the case of quotations of maximum and minimum limits. Should it be necessary to clarify whether a fuel meets the requirements of the specifications, the terms of ISO 4259 shall be applied.
- 2 The actual sulphur content of the fuel used for the emission tests shall be reported.
- 3 Ethanol to meet specification of EN 15376 is the only oxygenate that shall be intentionally added to this reference fuel.
- 4 The unleaded petrol content can be determined as 100 minus the sum of the % content of water, alcohols, MTBE and ETBE.
- 5 There shall be no intentional addition of compounds containing phosphorus, iron, manganese, or lead to this reference fuel.

### 3. Technical data on gaseous fuels for single-fuel and dual-fuel engines

#### 3.1. Type: LPG

<i>Parameter</i>	<i>Unit</i>	<i>Fuel A</i>	<i>Fuel B</i>	<i>Test method</i>
Composition:				EN 27941
C <sub>3</sub> -content	% v/v	30 ± 2	85 ± 2	
C <sub>4</sub> -content	% v/v	Balance <sup>1</sup>	Balance <sup>1</sup>	
< C <sub>3</sub> , > C <sub>4</sub>	% v/v	Maximum 2	Maximum 2	
Olefins	% v/v	Maximum 12	Maximum 15	
Evaporation residue	mg/kg	Maximum 50	Maximum 50	EN 15470
Water at 0 °C		Free	Free	EN 15469
Total sulphur content including odorant	mg/kg	Maximum 10	Maximum 10	EN 24260, ASTM D 3246, ASTM 6667
Hydrogen sulphide		None	None	EN ISO 8819
Copper strip corrosion (1h at 40 °C)	Rating	Class 1	Class 1	ISO 6251 <sup>2</sup>
Odour		Characteristic	Characteristic	
Motor octane number <sup>3</sup>		Minimum 89,0	Minimum 89,0	EN 589 Annex B
<i>Notes:</i>				
<sup>1</sup> Balance shall be read as follows: balance = 100 - C <sub>3</sub> - <C <sub>3</sub> - >C <sub>4</sub> .				
<sup>2</sup> This method may not accurately determine the presence of corrosive materials if the sample contains corrosion inhibitors or other chemicals which diminish the corrosivity of the sample to the copper strip. Therefore, the addition of such compounds for the sole purpose of biasing the test method is prohibited.				
<sup>3</sup> At the request of the engine manufacturer, a higher MON could be used to perform the type approval tests.				

### 3.2. Type: Natural Gas/ Biomethane

#### 3.2.1. Specification for reference fuels supplied with fixed properties (eg from a sealed container)

As an alternative to the reference fuels set out in this point, the equivalent fuels in point 3.2.2. may be used

Characteristics	Units	Basis	Limits		Test method
			minimum	maximum	
<b>Reference fuel G<sub>R</sub></b>					
Composition:					
Methane		87	84	89	
Ethane		13	11	15	
Balance <sup>1</sup>	% mole	—	—	1	ISO 6974
Sulphur content	mg/m <sup>3</sup> <sup>2</sup>	—		10	ISO 6326-5
<i>Notes:</i> <sup>1</sup> Inerts + C <sub>2+</sub> <sup>2</sup> Value to be determined at standard conditions 293,2 K (20 °C) and 101,3 kPa.					
<b>Reference fuel G<sub>23</sub></b>					
Composition:					
Methane		92,5	91,5	93,5	
Balance <sup>1</sup>	% mole	—	—	1	ISO 6974
N <sub>2</sub>	% mole	7,5	6,5	8,5	
Sulphur content	mg/m <sup>3</sup> <sup>2</sup>	—	—	10	ISO 6326-5
<i>Notes:</i> <sup>1</sup> Inerts (different from N <sub>2</sub> ) + C <sub>2+</sub> C <sub>2+</sub> <sup>2</sup> Value to be determined at 293,2 K (20 °C) and 101,3 kPa.					
<b>Reference fuel G<sub>25</sub></b>					
Composition:					
Methane	% mole	86	84	88	
Balance <sup>1</sup>	% mole	—	—	1	ISO 6974
N <sub>2</sub>	% mole	14	12	16	
Sulphur content	mg/m <sup>3</sup> <sup>2</sup>	—	—	10	ISO 6326-5
<i>Notes:</i> <sup>1</sup> Inerts (different from N <sub>2</sub> ) + C <sub>2+</sub> C <sub>2+</sub> <sup>2</sup> Value to be determined at 293,2 K (20 °C) and 101,3 kPa.					



Reference fuel G <sub>20</sub>					
Composition:					
Methane	% mole	100	99	100	ISO 6974
Balance <sup>(1)</sup>	% mole	—	—	1	ISO 6974
N <sub>2</sub>	% mole				ISO 6974
Sulphur content	mg/m <sup>3</sup> <sup>(2)</sup>	—	—	10	ISO 6326-5
Wobbe Index (net)	MJ/m <sup>3</sup> <sup>(3)</sup>	48,2	47,2	49,2	
<sup>(1)</sup> Inerts (different from N <sub>2</sub> ) + C <sub>2</sub> + C <sub>2</sub> +. <sup>(2)</sup> Value to be determined at 293,2 K (20 °C) and 101,3 kPa. <sup>(3)</sup> Value to be determined at 273,2 K (0 °C) and 101,3 kPa.					

3.2.2. Specification for reference fuel supplied from a pipeline with admixture of other gases with gas properties determined by on-site measurement

As an alternative to the reference fuels in this point the equivalent reference fuels in point 3.2.1. may be used.

3.2.2.1. The basis of each pipeline reference fuel (G<sub>R</sub>, G<sub>20</sub>, ...) shall be gas drawn from a utility gas distribution network, blended, where necessary to meet the corresponding lambda-shift (S<sub>λ</sub>) specification in Table 9.1., with an admixture of one or more of the following commercially<sup>1</sup> available gases:

- (a) Carbon dioxide;
- (b) Ethane;
- (c) Methane;
- (d) Nitrogen;
- (e) Propane.

<sup>1</sup> The use of calibration gas for this purpose shall not be required

3.2.2.2. The value of S<sub>λ</sub> of the resulting blend of pipeline gas and admixture gas shall be within the range specified in Table 9.1. for the specified reference fuel.

Table 9.1.

**Required range of S<sub>λ</sub> for each reference fuel**

Reference fuel	Minimum S <sub>λ</sub>	Maximum S <sub>λ</sub>
G <sub>R</sub> <sup>2</sup>	0,87	0,95
G <sub>20</sub>	0,97	1,03

G <sub>23</sub>	1,05	1,10
G <sub>25</sub>	1,12	1,20
<sup>2</sup> The engine shall not be required to be tested on a gas blend with a Methane Number (MN) less than 70. In the case that the required range of S <sub>λ</sub> for G <sub>R</sub> would result in an MN less than 70 the value of S <sub>λ</sub> for G <sub>R</sub> may be adjusted as necessary until a value of MN no less than 70 is attained.		

3.2.2.3. The engine test report for each test run shall include the following:

- (a) The admixture gas(es) chosen from the list in point 3.2.2.1.;
- (b) The value of S<sub>λ</sub> for the resulting fuel blend;
- (c) The Methane Number (MN) of the resulting fuel blend.

3.2.2.4. The requirements of Appendices 1 and 2 shall be met in respect to determination of the properties of the pipeline and admixture gases, the determination of S<sub>λ</sub> and MN for the resulting gas blend, and the verification that the blend was maintained during the test.

3.2.2.5. In the case that one or more of the gas streams (pipeline gas or admixture gas(es)) contain CO<sub>2</sub> in greater than a de-minimus proportion, the calculation of specific CO<sub>2</sub> emissions in Annex VII shall be corrected according to Appendix 3.

## Appendix 1

### **Supplementary requirements for conducting emission testing using gaseous reference fuels comprising pipeline gas with admixture of other gases**

#### **1. Method of gas analysis and gas flow measurement**

- 1.1. For the purpose of this Appendix, where required the composition of the gas shall be determined by analysis of the gas using gas chromatography according to EN ISO 6974, or by an alternative technique that achieves at least a similar level of accuracy and repeatability.
- 1.2. For the purpose of this Appendix, where required the measurement of gas flow shall be performed using a mass-based flowmeter.

#### **2. Analysis and flowrate of incoming utility gas supply**

- 2.1. The composition of the utility gas supply shall be analysed prior to the admixture blending system.
- 2.2. The flowrate of the utility gas entering the admixture blending system shall be measured.

#### **3. Analysis and flowrate of admixture**

- 3.1. When an applicable certificate of analysis is available for an admixture (for example issued by the gas supplier) this may be used as the source of that admixture composition. In this case the on-site analysis of that admixture composition shall be permitted but shall not be required.
- 3.2. Where an applicable certificate of analysis is not available for an admixture the composition of that admixture shall be analysed.
- 3.3. The flowrate of each admixture entering the admixture blending system shall be measured.

#### **4. Analysis of blended gas**

- 4.1. The analysis of the composition of the gas supplied to the engine after leaving the admixture blending system shall be permitted in addition to, or as an alternative to the analysis required by points 2.1. and 3.1., but shall not be required.

#### **5. Calculation of $S_\lambda$ and MN of the blended gas**

- 5.1. The results of the gas analysis according to point 2.1., point 3.1. or 3.2. and, where applicable, point 4.1., combined with the mass flowrate of gas measured according to points 2.2. and 3.3., shall be used to calculate the MN according to EN16726:2015. The same set of data shall be used to calculate  $S_\lambda$  according to the procedure set out in Appendix 2.

## **6. Control and verification of gas blend during the test**

- 6.1 The control and verification of the gas blend during the test shall be performed using either an open loop or closed loop control system.
- 6.2 Open loop blend control system
  - 6.2.1 In this case the gas analysis, flow measurements and calculations set out in points 1., 2., 3. and 4. shall be performed prior to the emission test.
  - 6.2.2 The proportion of utility gas and admixture(s) shall be set to ensure that the  $S_\lambda$  is within the permitted range for the relevant reference fuel in Table 9.1..
  - 6.2.3 When the relative proportions have been set they shall be maintained throughout the emission test. Adjustments to individual flow rates to maintain the relative proportions shall be permitted.
  - 6.2.4 When the emission test has been completed the analysis of gas composition, flow measurements and calculations set out in points 2., 3., 4. and 5. shall be repeated. In order for the test to be considered valid the value of  $S_\lambda$  shall remain within the specified range for the respective reference fuel given in Table 9.1..
- 6.3 Closed loop blend control system
  - 6.3.1 In this case the analysis of gas composition, flow measurements and calculations set out in points 2., 3., 4. and 5. shall be performed at intervals during the emission test. The intervals shall be chosen taking into consideration the frequency capability of the gas chromatograph and corresponding calculation system.
  - 6.3.2 The results from the periodic measurements and calculations shall be used to adjust the relative proportions of utility gas and admixture in order to maintain the value of  $S_\lambda$  within the range specified in Table 9.1. for the respective reference fuel. The frequency of adjustment shall not exceed the frequency of measurement.
  - 6.3.3 In order for the test to be considered valid the value of  $S_\lambda$  shall be within the range specified in Table 9.1. for the respective reference fuel for at least 90 % of the measurement points.

## Appendix 2

### Calculation of $\lambda$ -Shift factor ( $S_\lambda$ )

#### 1. Calculation

The  $\lambda$ -shift factor ( $S_\lambda$ )<sup>1</sup> shall be calculated by means of equation (9-1):

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert}\%}{100}\right) \left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} \quad (9-1)$$

Where:

$S_\lambda$  =  $\lambda$ -shift factor;

inert % = % by volume of inert gases in the fuel (i.e. N<sub>2</sub>, CO<sub>2</sub>, He, etc.);

O<sub>2</sub><sup>\*</sup> = % by volume of original oxygen in the fuel;

n and m = refer to average C<sub>n</sub>H<sub>m</sub> representing the fuel hydrocarbons, i.e:

$$n = \frac{1 \times \left[\frac{\text{CH}_4\%}{100}\right] + 2 \times \left[\frac{\text{C}_2\%}{100}\right] + 3 \times \left[\frac{\text{C}_3\%}{100}\right] + 4 \times \left[\frac{\text{C}_4\%}{100}\right] + 5 \times \left[\frac{\text{C}_5\%}{100}\right] + \dots}{\frac{1 - \text{diluent}\%}{100}} \quad (9-2)$$

$$m = \frac{4 \times \left[\frac{\text{CH}_4\%}{100}\right] + 4 \times \left[\frac{\text{C}_2\text{H}_4\%}{100}\right] + 6 \times \left[\frac{\text{C}_2\text{H}_6\%}{100}\right] + \dots + 8 \times \left[\frac{\text{C}_3\text{H}_8\%}{100}\right] + \dots}{\frac{1 - \text{diluent}\%}{100}} \quad (9-3)$$

Where:

CH<sub>4</sub> = % by volume of methane in the fuel;

C<sub>2</sub> = % by volume of all C<sub>2</sub> hydrocarbons (e.g.: C<sub>2</sub>H<sub>6</sub>, C<sub>2</sub>H<sub>4</sub>, etc.) in the fuel;

C<sub>3</sub> = % by volume of all C<sub>3</sub> hydrocarbons (e.g.: C<sub>3</sub>H<sub>8</sub>, C<sub>3</sub>H<sub>6</sub>, etc.) in the fuel;

<sup>1</sup> Stoichiometric Air/Fuel ratios of automotive fuels - SAE J1829, June 1987. John B. Heywood, Internal combustion engine fundamentals, McGraw-Hill, 1988, Chapter 3.4 "Combustion stoichiometry" (pp. 68 to 72).

$C_4$  = % by volume of all  $C_4$  hydrocarbons (e.g.:  $C_4H_{10}$ ,  $C_4H_8$ , etc.) in the fuel;

$C_5$  = % by volume of all  $C_5$  hydrocarbons (e.g.:  $C_5H_{12}$ ,  $C_5H_{10}$ , etc.) in the fuel;

diluent = % by volume of dilution gases in the fuel (i.e.:  $O_2^*$ ,  $N_2$ ,  $CO_2$ , He, etc.).

2. Examples for the calculation of the  $\lambda$ -shift factor  $S_\lambda$ :

Example 1:  $G_{25}$ :  $CH_4 = 86\%$ ,  $N_2 = 14\%$  (by volume)

$$n = \frac{1 \times \left[ \frac{CH_4\%}{100} \right] + 2 \times \left[ \frac{C_2\%}{100} \right] + \dots}{\frac{1 - \text{diluent}\%}{100}} = \frac{1 \times 0.86}{1 - \frac{14}{100}} = \frac{0.86}{0.86} = 1$$

$$m = \frac{4 \times \left[ \frac{CH_4\%}{100} \right] + 4 \times \left[ \frac{C_2H_4\%}{100} \right] + \dots}{\frac{1 - \text{diluent}\%}{100}} = \frac{4 \times 0.86}{0.86} = 4$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert}\%}{100}\right) \left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{14}{100}\right) \times \left(1 + \frac{4}{4}\right)} = 1.16$$

Example 2:  $G_R$ :  $CH_4 = 87\%$ ,  $C_2H_6 = 13\%$  (by vol)

$$n = \frac{1 \times \left[ \frac{CH_4\%}{100} \right] + 2 \times \left[ \frac{C_2\%}{100} \right] + \dots}{\frac{1 - \text{diluent}\%}{100}} = \frac{1 \times 0.87 + 2 \times 0.13}{1 - \frac{0}{100}} = \frac{1.13}{1} = 1.13$$

$$m = \frac{4 \times \left[ \frac{CH_4\%}{100} \right] + 4 \times \left[ \frac{C_2H_4\%}{100} \right] + \dots}{\frac{1 - \text{diluent}\%}{100}} = \frac{4 \times 0.87 + 6 \times 0.13}{1} = 4.26$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert}\%}{100}\right) \left(n + \frac{m}{4}\right) - \frac{O_2^*}{100}} = \frac{2}{\left(1 - \frac{0}{100}\right) \times \left(1.13 + \frac{4.26}{4}\right)} = 0.911$$

Example 3: USA:  $CH_4 = 89\%$ ,  $C_2H_6 = 4,5\%$ ,  $C_3H_8 = 2,3\%$ ,  $C_6H_{14} = 0,2\%$ ,  $O_2 = 0,6\%$ ,  $N_2 = 4\%$

$$n = \frac{1 \times \left[ \frac{CH_4\%}{100} \right] + 2 \times \left[ \frac{C_2\%}{100} \right] + \dots}{\frac{1 - \text{diluent}\%}{100}} = \frac{1 \times 0.89 + 2 \times 0.045 + 3 \times 0.023 + 4 \times 0.002}{1 - \frac{0.64 + 4}{100}} = 1.11$$

$$m = \frac{4 \times \left[ \frac{CH_4\%}{100} \right] + 4 \times \left[ \frac{C_2H_4\%}{100} \right] + 6 \times \left[ \frac{C_2H_6\%}{100} \right] + \dots + 8 \times \left[ \frac{C_3H_8\%}{100} \right]}{1 - \frac{\text{diluent \%}}{100}} =$$

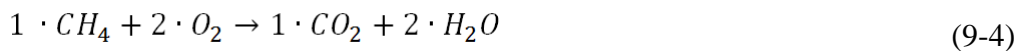
$$= \frac{4 \times 0.89 + 4 \times 0.045 + 8 \times 0.023 + 14 \times 0.002}{1 - \frac{0.6 + 4}{100}} = 4,24$$

$$S_\lambda = \frac{2}{\left(1 - \frac{\text{inert\%}}{100}\right) \left(n + \frac{m}{4}\right) - \frac{O^*}{100}} = \frac{2}{\left(1 - \frac{4}{100}\right) \times \left(1.11 + \frac{4.24}{4}\right) - \frac{0.6}{100}} = 0.96$$

As an alternative to the above equation,  $S_\lambda$  may be calculated from the ratio of the stoichiometric air demand of pure methane to the stoichiometric air demand of the fuel blend supplied to the engine, as specified below.

Lambda-shift factor ( $S_\lambda$ ) expresses the oxygen demand of any fuel blend in relation to oxygen demand of pure methane. Oxygen demand means the amount of oxygen to oxidise methane in a stoichiometric composition of reaction partners to products of complete combustion (i.e. carbon-dioxide and water).

For the combustion of pure methane the reaction is as set out in equation (9-4):



In this case the ratio of molecules in stoichiometric composition of reaction partners is exactly 2:

$$\frac{n_{O_2}}{n_{CH_4}} = 2$$

Where:

$n_{O_2}$  = number of molecules of oxygen

$n_{CH_4}$  = number of molecules of methane

The oxygen demand for pure methane is therefore:

$$n_{O_2} = 2 \cdot n_{CH_4} \text{ with a reference value of } [n_{CH_4}] = 1 \text{ kmol}$$

The value of  $S_\lambda$  may be determined from the ratio of the stoichiometric composition of oxygen and methane to the ratio of the stoichiometric composition of oxygen and the fuel blend supplied to the engine, as set out in equation (9-5):

$$S_\lambda = \frac{\left(\frac{n_{O_2}}{n_{CH_4}}\right)}{\left(\frac{n_{O_2}}{n_{blend}}\right)} = \frac{2}{(n_{O_2})_{blend}} \quad (9-5)$$

Where:

$n_{blend}$  = number of molecules of the fuel blend

$(n_{O_2})_{blend}$  = the ratio of the molecules in the stoichiometric composition of oxygen and the fuel blend supplied to the engine

Because air contains 21% oxygen the stoichiometric air demand  $L_{st}$  of any fuel shall be calculated by means of equation (9-6):

$$L_{st, fuel} = \frac{n_{O_2, fuel}}{0.21} \quad (9-6)$$

Where:

$L_{st, fuel}$  = the stoichiometric air demand for the fuel

$n_{O_2, fuel}$  = the stoichiometric oxygen demand for the fuel

Consequently the value of  $S_\lambda$  may also be determined from the ratio of the stoichiometric composition of air and methane to the ratio of the stoichiometric composition of air and the fuel blend supplied to the engine, i.e. the ratio of the stoichiometric air demand of methane to that of the fuel blend supplied to the engine, as set out in equation (9-7):

$$S_\lambda = \frac{\left(\frac{n_{O_2}}{n_{CH_4}}\right)/0.21}{\left(\frac{n_{O_2}}{n_{blend}}\right)/0.21} = \frac{\left(\frac{n_{O_2}}{0.21}\right)_{CH_4}}{\left(\frac{n_{O_2}}{0.21}\right)_{blend}} = \frac{L_{st, CH_4}}{L_{st, blend}} \quad (9-7)$$

Therefore, any calculation that specifies the stoichiometric air demand may be used to express the Lambda-shift factor.



## Appendix 3

### Correction for CO<sub>2</sub> in the exhaust gas arising from CO<sub>2</sub> in the gaseous fuel

#### 1. Instantaneous mass flow rate of CO<sub>2</sub> in the gaseous fuel stream

- 1.1. Gas composition and gas flow shall be determined according to the requirements of sections 1 to 4 of Appendix 1.
- 1.2. The instantaneous mass flow rate of CO<sub>2</sub> in a stream of gas supplied to the engine shall be calculated by means of equation (9-8).

$$\dot{m}_{\text{CO}_2\text{i}} = (M_{\text{CO}_2} / M_{\text{stream}}) * x_{\text{CO}_2\text{i}} * \dot{m}_{\text{streami}} \quad (9-8)$$

Where:

$\dot{m}_{\text{CO}_2\text{i}}$  = Instantaneous mass flow rate of CO<sub>2</sub> from the gas stream [g/s]

$\dot{m}_{\text{streami}}$  = Instantaneous mass flow rate of the gas stream [g/s]

$x_{\text{CO}_2\text{i}}$  = Molar fraction of CO<sub>2</sub> in the gaseous stream [-]

$M_{\text{CO}_2}$  = Molar mass of CO<sub>2</sub> [g/mol]

$M_{\text{stream}}$  = Molar mass of gas stream [g/mol]

$M_{\text{stream}}$  shall be calculated from all measured constituents (1, 2, ... , n) by means of equation (9-9).

$$M_{\text{stream}} = x_1 * M_1 + x_2 * M_2 + \dots + x_n * M_n \quad (9-9)$$

Where:

$X_{1,2,\dots,n}$  = Molar fraction of each measured constituent in the gas stream (CH<sub>4</sub>, CO<sub>2</sub>, ...) [-]

$M_{1,2,\dots,n}$  = Molar mass of each measured constituent in the gas stream [g/mol]

- 1.3. In order to determine the total mass flow rate of CO<sub>2</sub> in the gaseous fuel entering the engine the calculation in equation (9-8) shall be performed for each individual gas stream containing CO<sub>2</sub> that is entering the gas blending system and the result for each gas stream added together, or it shall be performed for the blended gas leaving the blending system and entering the engine by means of equation (9-10):

$$\dot{m}_{\text{CO}_2\text{i, fuel}} = \dot{m}_{\text{CO}_2\text{i, a}} + \dot{m}_{\text{CO}_2\text{i, b}} + \dots + \dot{m}_{\text{CO}_2\text{i, n}} \quad (9-10)$$

Where:

$\dot{m}_{\text{CO}_2\text{i, fuel}}$  = instantaneous combined mass flow rate of CO<sub>2</sub> arising from the CO<sub>2</sub> in the gaseous fuel entering the engine [g/s]

$\dot{m}_{\text{CO}_2\text{i, a, b, ..., n}}$  = instantaneous mass flow rate of CO<sub>2</sub> arising from the CO<sub>2</sub> in each individual gas stream a, b, ..., n [g/s]

2. Calculation of specific CO<sub>2</sub> emissions for transient (NRTC and LSI-NRTC) test cycles and RMC

2.1 The total mass per test of CO<sub>2</sub> emission from the CO<sub>2</sub> in the fuel  $m_{\text{CO}_2, \text{fuel}}$  [g/test] shall be calculated by summation of the instantaneous mass flow rate of CO<sub>2</sub> in the gaseous fuel entering the engine  $\dot{m}_{\text{CO}_2\text{i, fuel}}$  [g/s] over the test cycle by means of equation (9-11):

$$m_{\text{CO}_2, \text{fuel}} = \frac{1}{f} \cdot \sum_{i=1}^N \dot{m}_{\text{CO}_2\text{i, fuel}} \quad (9-11)$$

Where:

$f$  = data sampling rate [Hz]

$N$  = number of measurements [-]

2.2 The total mass of CO<sub>2</sub> emission  $m_{\text{CO}_2}$  [g/test] used in equation (7-61), (7-63), (7-128) or (7-130) of Annex VII to calculate the specific emissions result  $e_{\text{CO}_2}$  [g/kWh] shall be replaced in those equations by the corrected value  $m_{\text{CO}_2, \text{corr}}$  [g/test] calculated by means of equation (9-12).

$$m_{\text{CO}_2, \text{corr}} = m_{\text{CO}_2} - m_{\text{CO}_2, \text{fuel}} \quad (9-12)$$

3. Calculation of specific CO<sub>2</sub> emissions for discrete-mode NRSC

3.1 The mean mass flow of CO<sub>2</sub> emission from the CO<sub>2</sub> in the fuel per hour  $q_{m\text{CO}_2, \text{fuel}}$  or  $\dot{m}_{\text{CO}_2, \text{fuel}}$  [g/h] shall be calculated for each individual test mode from the measurements of instantaneous mass flow rate of CO<sub>2</sub>  $\dot{m}_{\text{CO}_2\text{i, fuel}}$  [g/s] given by equation (9-10) taken during the sampling period of the respective test mode by means of equation (9-13):

$$q_{m\text{CO}_2, \text{fuel}} = \dot{m}_{\text{CO}_2, \text{fuel}} = \frac{1}{3600 \cdot N} \cdot \sum_{i=1}^N \dot{m}_{\text{CO}_2\text{i, fuel}} \quad (9-13)$$

Where:

$N$  = number of measurements taken during the test mode [-]

3.2 The mean mass flow rate of CO<sub>2</sub> emission  $q_{m\text{CO}_2}$  or  $\dot{m}_{\text{CO}_2}$  [g/h] for each individual test mode used in equation (7-64) or (7-131) of Annex VII to calculate the specific emissions result  $e_{\text{CO}_2}$  [g/kWh] shall be replaced in those equations by the corrected value  $q_{m\text{CO}_2, \text{corr}}$  or  $\dot{m}_{\text{CO}_2, \text{corr}}$  [g/h] for each individual test mode calculated by means of equation (9-14) or (9-15).

$$q_{m\text{CO}_2, \text{corr}} = q_{m\text{CO}_2} - q_{m\text{CO}_2, \text{fuel}} \quad (9-14)$$

$$\dot{m}_{\text{CO}_2, \text{corr}} = \dot{m}_{\text{CO}_2} - \dot{m}_{\text{CO}_2, \text{fuel}}$$

(9-15)

## ANNEX X

### Detailed technical specifications and conditions for delivering an engine separately from its exhaust after-treatment system

1. Separate shipment, as set out in Article 34(3) of Regulation (EU) 2016/1628, occurs when the manufacturer and the OEM installing the engine are separate legal entities and the engine is shipped by the manufacturer from one location separately from its exhaust after-treatment system, and the exhaust after-treatment system is delivered from a different location and / or at a different moment in time.
2. In this case, the manufacturer shall:
  - 2.1. Be considered responsible for the placing on the market of the engine and for ensuring that the engine is brought into conformity with the approved engine type;
  - 2.2. Place all orders for the parts shipped separately before shipping the engine separately from its exhaust after-treatment system to the OEM;
  - 2.3. Make available to the OEM the instructions for installation of the engine, including the exhaust after-treatment system, and the identification marking of the parts shipped separately as well as the information necessary for checking the proper functioning of the assembled engine according to the approved engine type or engine family.
  - 2.4. Keep records of:
    - (1) the instructions made available to the OEM;
    - (2) the list of all parts delivered separately;
    - (3) the records returned from the OEM confirming that the engines delivered have been brought into conformity in accordance with section 3.;
  - 2.4.1. keep these records for at least 10 years;
  - 2.4.2. Make the records available to the approval authority, the European Commission or market surveillance authorities upon request.
- 2.5. Ensure that, in addition to the statutory marking required by Article 32 of Regulation (EU) 2016/1628, a temporary marking is affixed to the engine without exhaust after-treatment system, as required by Article 33(1) of that Regulation and in accordance with the provisions set out Annex III to Commission Implementing Regulation 2016/CCC on administrative requirements.
- 2.6. Ensure that the parts shipped separately from the engines have identification marking (for example part numbers).
- 2.7. Ensure that in the case of a transition engine, the engine (inclusive of the exhaust after-treatment system) has an engine production date prior to the date for placing on

the market of engines set out in Annex III to Regulation (EU) 2016/1628, as required by Article 3(7), Article 3(30) and Article 3(32) of that Regulation.

- 2.7.1. The records set out in point 2.4 shall include evidence that the exhaust after-treatment system that is part of a transition engine was produced prior to the said date in the case that the production date is not apparent from the marking on the exhaust after-treatment system.
3. The OEM shall:
  - 3.1. Confirm to the manufacturer that the engine has been brought into conformity with the approved engine type or engine family according to the instructions received and that all checks necessary to ensure the proper functioning of the assembled engine according to the approved engine type have been conducted.
  - 3.2. Where an OEM receives a regular supply of engines from a manufacturer the confirmation set out in point 3.1. may be provided at regular intervals agreed between the parties, but not exceeding one year.

## **ANNEX XI**

### **Detailed technical specifications and conditions for the temporary placing on the market for the purposes of field testing**

The following conditions shall apply for the temporary placing on the market of engines for the purpose of field testing in accordance with Article 34(4) of Regulation (EU) 2016/1628:

1. The ownership of the engine shall remain with the manufacturer until the procedure set out in point 5. is completed. This does not preclude a financial arrangement with the OEM or end-users who participates in the test procedure.
2. Before placing the engine on the market, the manufacturer shall inform the approval authority of a Member State, indicating his name or trade mark, the unique engine identification number of the engine, the production date of the engine, any relevant information on the emission performance of the engine and the OEM or end-users who participates in the test procedure.
3. The engine shall be accompanied by a statement of conformity delivered by the manufacturer and complying with the provisions set out in Annex II to Commission Implementing Regulation 2016/CCC on administrative requirements; the statement of conformity shall indicate, in particular, that it is a field testing engine temporarily placed on the market in accordance with Article 34(4) of Regulation (EU) 2016/1628.
4. The engine shall bear the statutory marking set out in Annex III to Commission Implementing Regulation 2016/CCC on administrative requirements;
5. When the tests have been completed and in any case 24 months from the placing on the market of the engine, the manufacturer shall ensure that the engine is either withdrawn from the market or brought into conformity with Regulation (EU) 2016/1628. The manufacturer shall inform the authorising approval authority of the option taken.
6. Notwithstanding point 5., the manufacturer may apply for an extension of the duration of the test for up to 24 additional months, before the same approval authority providing due justification for the extension request.
  - 6.1. The approval authority may authorise the extension, if deemed justified. In this case:
    - (1) a new statement of conformity shall be issued by the manufacturer for the additional period; and
    - (2) the provisions set out in point 5 shall apply by the end of the extension period or, in any case, 48 months after placing the engine on the market.

## **ANNEX XII**

### **Detailed technical specifications and conditions for special purpose engines**

The following conditions shall apply for placing on the market of engines that meet the gaseous and particulate pollutant emission limit values for special purpose engines set out in Annex VI to Regulation (EU) 2016/1628:

1. Before placing the engine on the market, the manufacturer shall take reasonable measures to ensure that the engine will be installed in a non-road mobile machinery to be exclusively used in potentially explosive atmospheres, in accordance with Article 35(5) of that Regulation, or for the launch and recovery of lifeboats operated by a national rescue service, in accordance with Article 35(6) of that Regulation.
2. For the purposes of point 1., a written statement from the OEM or economic operator receiving the engine confirming that it will be installed in a non-road mobile machinery to be exclusively used for such special purposes, shall be considered a reasonable measure.
3. The manufacturer shall:
  - (1) keep the written statement set out in point 2. for at least 10 years; and
  - (2) make it available to the approval authority, the European Commission or market surveillance authorities upon request.
4. The engine shall be accompanied by a statement of conformity delivered by the manufacturer and complying with the provisions set out in Annex II to Commission Implementing Regulation 2016/CCC on administrative requirements; the statement of conformity shall indicate, in particular, that it is a special purpose engine placed on the market under the conditions set out in Article 34(5) or 34(6) of Regulation (EU) 2016/1628.
5. The engine shall bear the statutory marking set out in Annex III to Commission Implementing Regulation 2016/CCC on administrative requirements.

## **ANNEX XIII**

### **Acceptance of equivalent engine type-approvals**

1. For engine families or engines types of category NRE the following type-approvals and, where applicable, the corresponding statutory marking, shall be recognised as equivalent to EU type-approvals granted and statutory marking required in accordance with Regulation (EU) 2016/1628:
  - (1) EU type-approvals granted on the basis of Regulation (EC) No 595/2009 and its implementing measures, where a technical service confirms that the engine type meets:
    - (a) the requirements set out in Appendix 2 of Annex IV, when the engine is exclusively intended for use in the place of Stage V engines of categories IWP and IWA, in accordance with Article 4(1), point (1)(b) of Regulation (EU) 2016/1628, or
    - (b) the requirements set out in Appendix 1 of Annex IV for engines not covered by paragraph (a);
  - (2) type-approvals in conformity with UNECE Regulation No 49.06 series of amendments, when a technical service confirms that the engine type meets:
    - (a) the requirements set out in Appendix 2 of Annex IV, when the engine is exclusively intended for use in the place of Stage V engines of categories IWP and IWA, in accordance with Article 4(1), point (1)(b) of Regulation (EU) 2016/1628, or
    - (b) the requirements set out in Appendix 1 of Annex IV for engines not covered by paragraph (a);



## ANNEX XIV

### Details of the relevant information and instructions for OEMs

1. As required by Article 43(2) of Regulation (EU) 2016/1628, the manufacturer shall provide to the OEM all relevant information and instructions to ensure that the engine conforms to the approved engine type when installed in non-road mobile machinery. Instructions for this purpose shall be clearly identified to the OEM.
2. The instructions may be provided on paper or a commonly used electronic format.
3. Where a number of engines requiring the same instructions are supplied to the same OEM it shall be necessary to provide only one set of instructions.
4. The information and instructions to the OEM shall include at least:
  - (1) installation requirements to achieve the emissions performance of the engine type, including the emissions control system, that shall be taken into account to ensure the correct operation of the emissions control system;
  - (2) a description of any special conditions or restrictions linked to the installation or use of the engine, as noted on the EU type-approval certificate set out in Annex IV to Commission Implementing Regulation (EU) 2016/CCC on administrative requirements;
  - (3) a statement indicating that the installation of the engine shall not permanently constrain the engine to exclusively operate within a power range corresponding to a (sub-)category with gaseous and particulate pollutant emission limits more stringent than the (sub-)category the engine belongs to;
  - (4) for engine families to which Annex V applies, the upper and lower boundaries of the applicable control area and a statement indicating that the installation of the engine shall not constrain the engine to exclusively operate at speed and load points outside of the control area for the torque curve of the engine;
  - (5) where applicable, design requirements for the components supplied by the OEM that are not part of the engine and are necessary to ensure that, when installed, the engine conforms to the approved engine type;
  - (6) where applicable, design requirements for the reagent tank, including freeze protection, monitoring of reagent level and means to take samples of reagent;
  - (7) where applicable, information on the possible installation of a non-heated reagent system;
  - (8) where applicable, a statement indicating that the engine is exclusively intended for installation in snow throwers;
  - (9) where applicable, a statement indicating that the OEM shall provide a warning system as set out in Appendices 1 to 4 of Annex IV;

- (10) where applicable, information on the interface between the engine and the non-road mobile machinery for the operator warning system, referred to in point (9);
- (11) where applicable, information on the interface between the engine and the non-road mobile machinery for the operator inducement system, as set out in section 5. of Appendix 1 of Annex IV;
- (12) where applicable, information on a means to temporarily disable the operator inducement as defined in point 5.2.1. of Appendix 1 of Annex IV;
- (13) where applicable, information on the inducement override function as defined in point 5.5. of Appendix 1 of Annex IV;
- (14) in the case of dual-fuel engines:
  - (a) a statement indicating that the OEM shall provide a dual-fuel operating mode indicator as described in point 4.3.1. of Annex VIII,
  - (b) a statement indicating that the OEM shall provide a dual-fuel warning system as described in point 4.3.2. of Annex VIII,
  - (c) information on the interface between the engine and the non-road mobile machinery for the operator indication and warning system, referred to in points (14)(a) and (b);
- (15) in the case of a variable speed engine of category IWP that is type-approved for use in one or more other inland waterway application as set out in point 1.1.1.2. of Annex IX to Commission Implementing Regulation (EU) 2016/CCC on administrative requirements, the details of each (sub-)category and operating mode (speed operation) for which the engine is type approved and may be set when installed;
- (16) In the case of a constant-speed engine equipped with alternative speeds as set out in section 1.1.2.3 of Annex IX to Commission Implementing Regulation (EU) 2016/CCC on administrative requirements:
  - (a) a statement indicating that the installation of the engine shall ensure that:
    - i. the engine is stopped prior to resetting the constant-speed governor to an alternative speed; and,
    - ii. the constant-speed governor is only set to the alternative speeds permitted by the engine manufacturer;
  - (b) details of each (sub-)category and operating mode (speed operation) for which the engine is type-approved and may be set when installed;
- (17) In the case that the engine is equipped with an idle speed for start-up and shut-down, as permitted by Article 3 (18) of Regulation (EU) 2016/1628, a statement indicating that the installation of the engine shall ensure that the

constant-speed governor function is engaged prior to increasing the load-demand to the engine from the no-load setting.

5. As required by Article 43(3) of Regulation (EU) 2016/1628, the manufacturer shall provide to the OEM all information and necessary instructions that the OEM shall provide to the end-users in accordance with Annex XV.
6. As required by Article 43(4) of Regulation (EU) 2016/1628, the manufacturer shall provide to the OEM the value of the carbon dioxide (CO<sub>2</sub>) emissions in g/kWh determined during the EU type-approval process and recorded in EU type-approval certificate. This value shall be provided by the OEM to the end-users accompanied of the following statement: *'This CO<sub>2</sub> measurement results from testing over a fixed test cycle under laboratory conditions a(n) (parent) engine representative of the engine type (engine family) and shall not imply or express any guarantee of the performance of a particular engine'*.

## ANNEX XV

### Details of the relevant information and instructions for end-users

1. The OEM shall provide to the end-users all information and necessary instructions for the correct operation of the engine in order to maintain the gaseous and particulate pollutant emissions of the engine within the limits of the approved engine type or engine family. Instructions for this purpose shall be clearly identified to the end-users.
2. The instructions to the end-users shall be:
  - 2.1. written in a clear and non-technical manner using the same language that is used in the instructions to end-users for the non-road mobile machinery;
  - 2.2. be provided on paper or, alternatively, a commonly used electronic format;
  - 2.3. be part of the instructions to end-users for the non-road machinery or, alternatively, a separate document;
    - 2.3.1. when delivered separately from the instructions to end-users for the non-road machinery, be provided in the same form;
3. The information and instructions to the end-users shall include at least:
  - (1) a description of any special conditions or restrictions linked to the use of the engine, as noted on the EU type-approval certificate set out in Annex IV to Commission Implementing Regulation (EU) 2016/CCC on administrative requirements;
  - (2) a statement indicating that the engine, including the emissions control system, shall be operated, used and maintained in accordance with the instructions provided to the end-users in order to maintain the emissions performance of the engine within the requirements applicable to the engine's category;
  - (3) a statement indicating that no deliberate tampering with or misuse of the engine emissions control system should take place; in particular with regard to deactivating or not maintaining an exhaust gas recirculation (EGR) or a reagent dosing system.
  - (4) a statement indicating that it is essential to take prompt action to rectify any incorrect operation, use or maintenance of the emissions control system in accordance with the rectification measures indicated by the warnings referred to in points (5) and (6);
  - (5) detailed explanations of the possible malfunctions of the emissions control system generated by incorrect operation, use or maintenance of the installed engine, accompanied by the associated warning signals and the corresponding rectification measures;

- (6) detailed explanations of the possible incorrect use of the non-road mobile machinery that would result in malfunctions of the engine emissions control system, accompanied by the associated warning signals and the corresponding rectification measures;
- (7) where applicable, information on the possible use of a non-heated reagent tank and dosing system;
- (8) where applicable, a statement indicating that the engine is exclusively intended for use in snow throwers;
- (9) for non-road mobile machinery with an operator warning system, as defined in section 4. Appendix 1 of Annex IV (category: NRE, NRG, IWP, IWA or RLR) and/or section 4. of Appendix 4 of Annex IV (category: NRE, NRG, IWP, IWA or RLR) or section 3. of Appendix 3 of Annex IV (category RLL), a statement indicating that the operator will be informed by the operator warning system when the emission control system does not function correctly;
- (10) for non-road mobile machinery with an operator inducement system as defined in section 5. of Appendix 1 of Annex IV (category NRE, NRG), a statement indicating that ignoring the operator warning signals will lead to the activation of the operator inducement system, resulting in an effective disablement of non-road mobile machinery operation;
- (11) for non-road mobile machinery with an inducement override function as defined in point 5.5. of Appendix 1 of Annex IV for releasing full engine power, information about the operation of this function;
- (12) where applicable, explanations of how the operator warning and inducement systems referred to in points (9), (10) and (11) operate, including the consequences, in terms of performance and fault logging, of ignoring the warning system signals and of not replenishing, where used, the reagent or rectifying the problem identified;
- (13) where records in the on-board computer log of inadequate reagent injection or reagent quality are made in accordance with point 4.1. of Appendix 2 of Annex IV (category: IWP, IWA, RLR), an statement indicating that national inspection authorities will be able to read with a scan tool these records;
- (14) for non-road mobile machinery with a means to disable the operator inducement as defined in point 5.2.1. of Appendix 1 of Annex IV, information about the operation of this function, and a statement indicating that this function shall be only activated in case of emergencies, that any activation will be recorded in the on-board computer log and that national inspection authorities will be able to read these records with a scan tool;
- (15) information on the fuel specification(s) necessary to maintain the performance of the emissions control system following the requirements of Annex I and in consistency with the specifications set-out in the engine EU type-approval including, where available, reference to the appropriate EU or international standard, in particular:

- (a) where the engine is to be operated within the Union on diesel or non-road gas-oil, a statement indicating that a fuel with sulphur content not greater than 10 mg/kg (20 mg/kg at point of final distribution) cetane number not less than 45 and an FAME content not greater than 7 % v/v shall be used.
  - (b) where additional fuels, fuel mixtures or fuel emulsions are compatible with use by the engine, as declared by the manufacturer and stated in the EU type-approval certificate, these shall be indicated;
- (16) information on the lubrication oil specifications necessary to maintain the performance of the emissions control system;
- (17) where the emission control system requires a reagent, the characteristics of that reagent, including the type of reagent, information on concentration when the reagent is in solution, operational temperature conditions and reference to international standards for composition and quality, consistent with the specification set-out in the engine EU type-approval.
- (18) where applicable, instructions specifying how consumable reagents have to be refilled by the operator between normal maintenance intervals. They shall indicate how the operator should refill the reagent tank and the anticipated frequency of refill, depending upon utilisation of the non-road mobile machinery.
- (19) a statement indicating that in order to maintain the emissions performance of the engine, it is essential to use and refill reagent in accordance with the specifications set out in points (17) and (18);
- (20) scheduled emission-related maintenance requirements including any scheduled exchange of critical emission-related components;
- (21) in the case of dual fuel engines:
- (a) where applicable, information on the dual-fuel indicators set out in section 4.3. of Annex VIII,
  - (b) where a dual fuel engine has operability restrictions in a service mode as defined in point 4.2.2.1. of Annex VIII (excluding categories: IWP, IWA, RLL and RLR), a statement indicating that the activation of the service mode will result in an effective disablement of non-road mobile machinery operation,
  - (c) where an inducement override function for releasing full engine power is available, information about the operation of this function shall be provided,
  - (d) where a dual fuel engine operates in a service mode in accordance with point 4.2.2.2. of Annex VIII (categories: IWP, IWA, RLL and RLR), a statement indicating that the activation of the service mode will be recorded in the on-board computer log and that national inspection authorities will be able to read these records with a scan tool.

4. As required by Article 43(4) of Regulation (EU) 2016/1628, the OEM shall provide to the end-users the value of the carbon dioxide (CO<sub>2</sub>) emissions in g/kWh determined during the EU type-approval process and recorded in EU type-approval certificate accompanied of the following statement: *'This CO<sub>2</sub> measurement results from testing over a fixed test cycle under laboratory conditions a(n) (parent) engine representative of the engine type (engine family) and shall not imply or express any guarantee of the performance of a particular engine'*.

## Annex XVI

### Performance standards and assessment of technical services

#### **1. General Requirements**

Technical services shall demonstrate appropriate skills, specific technical knowledge and proven experience in the specific fields of competence covered by Regulation (EU) 2016/1628 and the delegated and implementing acts adopted pursuant to that Regulation.

#### **2. Standards with which the technical services have to comply**

- 2.1. Technical services of the different categories set out in Article 45 of Regulation (EU) 2016/1628 shall comply with the standards listed in Appendix 1 of Annex V to Directive 2007/46/EC of the European Parliament and of the Council<sup>2</sup> which are relevant for the activities they carry out.
- 2.2. Reference to Article 41 of Directive 2007/46/EC in that Appendix shall be construed as a reference to Article 45 of Regulation (EU) 2016/1628.
- 2.3. Reference to Annex IV of Directive 2007/46/EC in that Appendix shall be construed as a reference to Regulation (EU) 2016/1628 and the delegated and implementing acts adopted pursuant to that Regulation.

#### **3. Procedure for the assessment of the technical services**

- 3.1. The compliance of the Technical services with the requirements of Regulation (EU) 2016/1628 and the delegated and implementing acts adopted pursuant to that Regulation shall be assessed in accordance with the procedure set out in Appendix 2 of Annex V to Directive 2007/46/EC.
- 3.2. References to Article 42 of Directive 2007/46/EC in Appendix 2 of Annex V to Directive 2007/46/EC shall be construed as references to Article 48 of Regulation (EU) 2016/1628.

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<sup>2</sup> Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (OJ L 263, 9.10.2007, p. 1).



## **Annex XVII**

### **Characteristics of the steady-state and transient test cycles**

1. Tables of test modes and weighting factors for the discrete-mode NRSC are set out in Appendix 1.
2. Tables of test modes and weighting factors for the RMC are set out in Appendix 2.
3. Tables of engine dynamometer schedules for transient (NRTC and LSI-NRTC) test cycles are set out in Appendix 3.

## Appendix 1

### Steady-state discrete-mode NRSC

#### Test cycles type C

**Table of cycle C1 test modes and weighting factors**

Mode number	1	2	3	4	5	6	7	8
<b>Speed (a)</b>	100%				Intermediate			Idle
<b>Torque (b) (%)</b>	100	75	50	10	100	75	50	0
<b>Weighting factor</b>	0,15	0,15	0,15	0,1	0,1	0,1	0,1	0,15
<b>(a)</b> See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.								
<b>(b)</b> The % torque is relative to the maximum torque at the commanded engine speed.								

**Table of cycle C2 test modes and weighting factors**

Mode number	1	2	3	4	5	6	7
<b>Speed (a)</b>	100%	Intermediate					Idle
<b>Torque (b) (%)</b>	25	100	75	50	25	10	0
<b>Weighting factor</b>	0,06	0,02	0,05	0,32	0,30	0,10	0,15
<b>(a)</b> See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.							
<b>(b)</b> The % torque is relative to the maximum torque at the commanded engine speed.							

## Test cycles type D

**Table of cycle D2 test modes and weighting factors**

<b>Mode number</b> (cycle D2)	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Speed (a)</b>	100%				
<b>Torque (b) (%)</b>	100	75	50	25	10
<b>Weighting factor</b>	0,05	0,25	0,3	0,3	0,1
<p>(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.</p> <p>(b) % torque is relative to the torque corresponding to the rated net power declared by the manufacturer.</p>					

## Test cycles type E

**Table of cycles type E test modes and weighting factors**

<b>Mode number</b> (cycle E2)	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>						
<b>Speed (a)</b>	100%					Intermediate				
<b>Torque (b) (%)</b>	100	75	50	25						
<b>Weighting factor</b>	0,2	0,5	0,15	0,15						
<b>Mode number</b> (cycle E3)	<b>1</b>					<b>2</b>		<b>3</b>		<b>4</b>
<b>Speed (a) (%)</b>	100					91		80		63
<b>Power (c) (%)</b>	100					75		50		25
<b>Weighting factor</b>	0,2					0,5		0,15		0,15
<p>(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.</p> <p>(b) % torque is relative to the torque corresponding to the rated net power declared by the manufacturer at the commanded engine speed.</p> <p>(c) % power is relative to the maximum rated power at the 100 % speed.</p> <p>(d) % torque is relative to the torque corresponding to the rated net power.</p>										

## Test cycle type F

**Table of cycle type F test modes and weighting factors**

<b>Mode number</b>	<b>1</b>	<b>2 (d)</b>	<b>3</b>
<b>Speed (a)</b>	100%	Intermediate	Idle
<b>Power (%)</b>	100 (c)	50 (c)	5 (b)
<b>Weighting factor</b>	0,15	0,25	0,6
<p>(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.</p> <p>(b) % power at this mode is relative to the power at mode 1.</p> <p>(c) % power at this mode is relative to the maximum net power at the commanded engine speed.</p> <p>(d) For engines using a discrete control system (i.e. notch type controls) mode 2 is defined as an operation in the</p>			

notch closest to mode 2 or 35 % of the rated power.

## Test cycle type G

**Table of cycles type G test modes and weighting factors**

Mode number (cycle G1)						1	2	3	4	5	6
Speed (a)	100%					Intermediate					Idle
Torque (b) %						100	75	50	25	10	0
Weighting factor						0,09	0,20	0,29	0,30	0,07	0,05
Mode number (cycle G2)	1	2	3	4	5						6
Speed (a)	100%					Intermediate					Idle
Torque (b) %	100	75	50	25	10						0
Weighting factor	0,09	0,20	0,29	0,30	0,07						0,05
Mode number (cycle G3)	1										2
Speed (a)	100%					Intermediate					Idle
Torque (b) %	100										0
Weighting factor	0,85										0,15
(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.											
(b) The % torque is relative to the maximum torque at the commanded engine speed.											

## Test cycle type H

**Table of cycle type H test modes and weighting factors**

Mode number	1	2	3	4	5
Speed (a) (%)	100	85	75	65	Idle

<b>Torque (b) (%)</b>	100	51	33	19	0
<b>Weighting factor</b>	0,12	0,27	0,25	0,31	0,05
<p>(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.</p> <p>(b) % torque is relative to the maximum torque at the commanded engine speed.</p>					

## Appendix 2

### Steady-state ramped modal cycles (RMC)

#### Test cycles type C

**Table of RMC-C1 test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (a)(c)</b>	<b>Torque (%) (b)(c)</b>
1a Steady-state	126	Idle	0
1b Transition	20	Linear transition	Linear transition
2a Steady-state	159	Intermediate	100
2b Transition	20	Intermediate	Linear transition
3a Steady-state	160	Intermediate	50
3b Transition	20	Intermediate	Linear transition
4a Steady-state	162	Intermediate	75
4b Transition	20	Linear transition	Linear transition
5a Steady-state	246	100 %	100
5b Transition	20	100 %	Linear transition
6a Steady-state	164	100 %	10
6b Transition	20	100 %	Linear transition
7a Steady-state	248	100 %	75
7b Transition	20	100 %	Linear transition
8a Steady-state	247	100 %	50
8b Transition	20	Linear transition	Linear transition
9 Steady-state	128	Idle	0

**a)** See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

**(b)** % torque is relative to the maximum torque at the commanded engine speed.

**(c)** Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode, and simultaneously command a similar linear progression for engine speed if there is a change in speed setting.





**Table of RMC-C2 test modes**

<b>RMC Mode number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (a)(c)</b>	<b>Torque (%) (b)(c)</b>
1a Steady-state	119	Idle	0
1b Transition	20	Linear transition	Linear transition
2a Steady-state	29	Intermediate	100
2b Transition	20	Intermediate	Linear transition
3a Steady-state	150	Intermediate	10
3b Transition	20	Intermediate	Linear transition
4a Steady-state	80	Intermediate	75
4b Transition	20	Intermediate	Linear transition
5a Steady-state	513	Intermediate	25
5b Transition	20	Intermediate	Linear transition
6a Steady-state	549	Intermediate	50
6b Transition	20	Linear transition	Linear transition
7a Steady-state	96	100%	25
7b Transition	20	Linear transition	Linear transition
8 Steady-state	124	Idle	0

**(a)** See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

**(b)** % torque is relative to the maximum torque at the commanded engine speed.

**(c)** Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode, and simultaneously command a similar linear progression for engine speed if there is a change in speed setting.

## Test cycles type D

**Table of RMC-D2 test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (%) (a)</b>	<b>Torque (%) (b)(c)</b>
1a Steady State	53	100	100
1b Transition	20	100	Linear transition
2a Steady-state	101	100	10
2b Transition	20	100	Linear transition
3a Steady-state	277	100	75
3b Transition	20	100	Linear transition
4a Steady-state	339	100	25
4b Transition	20	100	Linear transition
5 Steady-state	350	100	50

(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

(b) % torque is relative to the torque corresponding to the rated net power declared by the manufacturer.

(c) Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode.

## Test cycles type E

**Table of RMC-E2 test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (%) (a)</b>	<b>Torque (%) (b)(c)</b>
1a Steady-state	229	100	100
1b Transition	20	100	Linear transition
2a Steady-state	166	100	25
2b Transition	20	100	Linear transition
3a Steady-state	570	100	75
3b Transition	20	100	Linear transition
4 Steady-state	175	100	50

**(a)** See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

**(b)** % torque is relative to the maximum torque corresponding to the rated net power declared by the manufacturer at the commanded engine speed.

**(c)** Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode.

**Table of RMC-E3 test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (%) (a)(c)</b>	<b>Power (%) (b)(c)</b>
1a Steady-state	229	100	100
1b Transition	20	Linear transition	Linear transition
2a Steady-state	166	63	25
2b Transition	20	Linear transition	Linear transition
3a Steady-state	570	91	75
3b Transition	20	Linear transition	Linear transition
4 Steady-state	175	80	50

(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

(b) % power is relative to the maximum rated net power at the 100% speed.

(c) Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode, and simultaneously command a similar linear progression for engine speed.

## Test cycle type F

**Table of RMC-F test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (a)(e)</b>	<b>Power (%) (e)</b>
1a Steady-state	350	Idle	5 (b)
1b Transition	20	Linear transition	Linear transition
2a Steady-state(d)	280	Intermediate	50 (c)
2b Transition	20	Linear transition	Linear transition
3a Steady-state	160	100 %	100 (c)
3b Transition	20	Linear Transition	Linear transition
4 Steady-state	350	Idle	5 (c)

(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

(b) % power at this mode is relative to the net power at mode 3a.

(c) % power at this mode is relative to the maximum net power at the commanded engine speed.

(d) For engines using a discrete control system (i.e. notch type controls) mode 2a is defined as an operation in the notch closest to mode 2a or 35 % of the rated power.

(e) Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode, and simultaneously command a similar linear progression for engine speed if there is a change in speed setting.

## Test cycles type G

**Table of RMC-G1 test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (a)(c)</b>	<b>Torque (%) (b)(c)</b>
1a Steady-state	41	Idle	0
1b Transition	20	Linear transition	Linear transition
2a Steady-state	135	Intermediate	100
2b Transition	20	Intermediate	Linear transition
3a Steady-state	112	Intermediate	10
3b Transition	20	Intermediate	Linear transition
4a Steady-state	337	Intermediate	75
4b Transition	20	Intermediate	Linear transition
5a Steady-state	518	Intermediate	25
5b Transition	20	Intermediate	Linear transition
6a Steady-state	494	Intermediate	50
6b Transition	20	Linear transition	Linear transition
7 Steady-state	43	Idle	0

(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

(b) The % torque is relative to the maximum torque at the commanded engine speed.

(c) Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode and simultaneously command a similar linear progression for engine speed if there is a change in speed setting.

**Table of RMC-G2 test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (a)(c)</b>	<b>Torque (%) (b)(c)</b>
1a Steady-state	41	Idle	0
1b Transition	20	Linear transition	Linear transition
2a Steady-state	135	100 %	100
2b Transition	20	100 %	Linear transition
3a Steady-state	112	100 %	10
3b Transition	20	100 %	Linear transition
4a Steady-state	337	100 %	75
4b Transition	20	100 %	Linear transition
5a Steady-state	518	100 %	25
5b Transition	20	100 %	Linear transition
6a Steady-state	494	100 %	50
6b Transition	20	Linear transition	Linear transition
7 Steady-state	43	Idle	0

**(a)** See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

**(b)** The % torque is relative to the maximum torque at the commanded engine speed.

**(c)** Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode and simultaneously command a similar linear progression for engine speed if there is a change in speed setting.

## Test cycle type H

**Table of RMC-H test modes**

<b>RMC Mode Number</b>	<b>Time in mode (seconds)</b>	<b>Engine speed (a)(c)</b>	<b>Torque (%) (b)(c)</b>
1a Steady-state	27	Idle	0
1b Transition	20	Linear transition	Linear transition
2a Steady-state	121	100%	100
2b Transition	20	Linear transition	Linear transition
3a Steady-state	347	65%	19
3b Transition	20	Linear transition	Linear transition
4a Steady-state	305	85%	51
4b Transition	20	Linear transition	Linear transition
5a Steady-state	272	75%	33
5b Transition	20	Linear transition	Linear transition
6 Steady-state	28	Idle	0

(a) See sections 5.2.5., 7.6. and 7.7. of Annex VI for determination of required test speeds.

(b) % torque is relative to the maximum torque at the commanded engine speed.

(c) Advance from one mode to the next within a 20-second transition phase. During the transition phase, command a linear progression from the torque setting of the current mode to the torque setting of the next mode, and simultaneously command a similar linear progression for engine speed if there is a change in speed setting.



**Appendix 3. 2.4.2.1. Transient (NRTC and LSI-NRTC) test cycles**

**NRTC engine dynamometer schedule**

Time (s)	Normalized speed (%)	Normalized torque (%)
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	0	0
10	0	0
11	0	0
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
23	0	0

Time (s)	Normalized speed (%)	Normalized torque (%)
24	1	3
25	1	3
26	1	3
27	1	3
28	1	3
29	1	3
30	1	6
31	1	6
32	2	1
33	4	13
34	7	18
35	9	21
36	17	20
37	33	42
38	57	46
39	44	33
40	31	0
41	22	27
42	33	43
43	80	49
44	105	47
45	98	70

46	104	36
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69	25	56
----	----	----

Time (s)	Normalized speed (%)	Normalized torque (%)
47	104	65
48	96	71
49	101	62
50	102	51
51	102	50
52	102	46
53	102	41
54	102	31
55	89	2
56	82	0
57	47	1
58	23	1
59	1	3
60	1	8
61	1	3
62	1	5
63	1	6
64	1	4
65	1	4
66	0	6
67	1	4
68	9	21

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
70	64	26
71	60	31
72	63	20
73	62	24
74	64	8
75	58	44
76	65	10
77	65	12
78	68	23
79	69	30
80	71	30
81	74	15
82	71	23
83	73	20
84	73	21
85	73	19
86	70	33
87	70	34
88	65	47
89	66	47
90	64	53
91	65	45

92	66	38
93	67	49
94	69	39
95	69	39

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
96	66	42
97	71	29
98	75	29
99	72	23
100	74	22
101	75	24
102	73	30
103	74	24
104	77	6
105	76	12
106	74	39
107	72	30
108	75	22
109	78	64
110	102	34
111	103	28
112	103	28
113	103	19
114	103	32
115	104	25
116	103	38
117	103	39

118	103	34
119	102	44
120	103	38
121	102	43

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
122	103	34
123	102	41
124	103	44
125	103	37
126	103	27
127	104	13
128	104	30
129	104	19
130	103	28
131	104	40
132	104	32
133	101	63
134	102	54
135	102	52
136	102	51
137	103	40
138	104	34
139	102	36
140	104	44
141	103	44
142	104	33
143	102	27

144	103	26
145	79	53
146	51	37
147	24	23

Time (s)	Normalized speed (%)	Normalized torque (%)
148	13	33
149	19	55
150	45	30
151	34	7
152	14	4
153	8	16
154	15	6
155	39	47
156	39	4
157	35	26
158	27	38
159	43	40
160	14	23
161	10	10
162	15	33
163	35	72
164	60	39
165	55	31
166	47	30
167	16	7
168	0	6
169	0	8

170	0	8
171	0	2
172	2	17
173	10	28

Time (s)	Normalized speed (%)	Normalized torque (%)
174	28	31
175	33	30
176	36	0
177	19	10
178	1	18
179	0	16
180	1	3
181	1	4
182	1	5
183	1	6
184	1	5
185	1	3
186	1	4
187	1	4
188	1	6
189	8	18
190	20	51
191	49	19
192	41	13
193	31	16
194	28	21
195	21	17

196	31	21
197	21	8
198	0	14
199	0	12

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
200	3	8
201	3	22
202	12	20
203	14	20
204	16	17
205	20	18
206	27	34
207	32	33
208	41	31
209	43	31
210	37	33
211	26	18
212	18	29
213	14	51
214	13	11
215	12	9
216	15	33
217	20	25
218	25	17
219	31	29
220	36	66
221	66	40

222	50	13
223	16	24
224	26	50
225	64	23

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
226	81	20
227	83	11
228	79	23
229	76	31
230	68	24
231	59	33
232	59	3
233	25	7
234	21	10
235	20	19
236	4	10
237	5	7
238	4	5
239	4	6
240	4	6
241	4	5
242	7	5
243	16	28
244	28	25
245	52	53
246	50	8
247	26	40

248	48	29
249	54	39
250	60	42
251	48	18

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
252	54	51
253	88	90
254	103	84
255	103	85
256	102	84
257	58	66
258	64	97
259	56	80
260	51	67
261	52	96
262	63	62
263	71	6
264	33	16
265	47	45
266	43	56
267	42	27
268	42	64
269	75	74
270	68	96
271	86	61
272	66	0
273	37	0



274	45	37
275	68	96
276	80	97
277	92	96

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
278	90	97
279	82	96
280	94	81
281	90	85
282	96	65
283	70	96
284	55	95
285	70	96
286	79	96
287	81	71
288	71	60
289	92	65
290	82	63
291	61	47
292	52	37
293	24	0
294	20	7
295	39	48
296	39	54
297	63	58
298	53	31
299	51	24

300	48	40
301	39	0
302	35	18
303	36	16

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
304	29	17
305	28	21
306	31	15
307	31	10
308	43	19
309	49	63
310	78	61
311	78	46
312	66	65
313	78	97
314	84	63
315	57	26
316	36	22
317	20	34
318	19	8
319	9	10
320	5	5
321	7	11
322	15	15
323	12	9
324	13	27
325	15	28

326	16	28
327	16	31
328	15	20
329	17	0

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
330	20	34
331	21	25
332	20	0
333	23	25
334	30	58
335	63	96
336	83	60
337	61	0
338	26	0
339	29	44
340	68	97
341	80	97
342	88	97
343	99	88
344	102	86
345	100	82
346	74	79
347	57	79
348	76	97
349	84	97
350	86	97
351	81	98

352	83	83
353	65	96
354	93	72
355	63	60

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
356	72	49
357	56	27
358	29	0
359	18	13
360	25	11
361	28	24
362	34	53
363	65	83
364	80	44
365	77	46
366	76	50
367	45	52
368	61	98
369	61	69
370	63	49
371	32	0
372	10	8
373	17	7
374	16	13
375	11	6
376	9	5
377	9	12

378	12	46
379	15	30
380	26	28
381	13	9

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
382	16	21
383	24	4
384	36	43
385	65	85
386	78	66
387	63	39
388	32	34
389	46	55
390	47	42
391	42	39
392	27	0
393	14	5
394	14	14
395	24	54
396	60	90
397	53	66
398	70	48
399	77	93
400	79	67
401	46	65
402	69	98
403	80	97

404	74	97
405	75	98
406	56	61
407	42	0

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
408	36	32
409	34	43
410	68	83
411	102	48
412	62	0
413	41	39
414	71	86
415	91	52
416	89	55
417	89	56
418	88	58
419	78	69
420	98	39
421	64	61
422	90	34
423	88	38
424	97	62
425	100	53
426	81	58
427	74	51
428	76	57
429	76	72

430	85	72
431	84	60
432	83	72
433	83	72

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
434	86	72
435	89	72
436	86	72
437	87	72
438	88	72
439	88	71
440	87	72
441	85	71
442	88	72
443	88	72
444	84	72
445	83	73
446	77	73
447	74	73
448	76	72
449	46	77
450	78	62
451	79	35
452	82	38
453	81	41
454	79	37
455	78	35

456	78	38
457	78	46
458	75	49
459	73	50

Time (s)	Normalized speed (%)	Normalized torque (%)
460	79	58
461	79	71
462	83	44
463	53	48
464	40	48
465	51	75
466	75	72
467	89	67
468	93	60
469	89	73
470	86	73
471	81	73
472	78	73
473	78	73
474	76	73
475	79	73
476	82	73
477	86	73
478	88	72
479	92	71
480	97	54
481	73	43

482	36	64
483	63	31
484	78	1
485	69	27

Time (s)	Normalized speed (%)	Normalized torque (%)
486	67	28
487	72	9
488	71	9
489	78	36
490	81	56
491	75	53
492	60	45
493	50	37
494	66	41
495	51	61
496	68	47
497	29	42
498	24	73
499	64	71
500	90	71
501	100	61
502	94	73
503	84	73
504	79	73
505	75	72
506	78	73
507	80	73

508	81	73
509	81	73
510	83	73
511	85	73

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
512	84	73
513	85	73
514	86	73
515	85	73
516	85	73
517	85	72
518	85	73
519	83	73
520	79	73
521	78	73
522	81	73
523	82	72
524	94	56
525	66	48
526	35	71
527	51	44
528	60	23
529	64	10
530	63	14
531	70	37
532	76	45
533	78	18

534	76	51
535	75	33
536	81	17
537	76	45

Time (s)	Normalized speed (%)	Normalized torque (%)
538	76	30
539	80	14
540	71	18
541	71	14
542	71	11
543	65	2
544	31	26
545	24	72
546	64	70
547	77	62
548	80	68
549	83	53
550	83	50
551	83	50
552	85	43
553	86	45
554	89	35
555	82	61
556	87	50
557	85	55
558	89	49
559	87	70

560	91	39
561	72	3
562	43	25
563	30	60

Time (s)	Normalized speed (%)	Normalized torque (%)
564	40	45
565	37	32
566	37	32
567	43	70
568	70	54
569	77	47
570	79	66
571	85	53
572	83	57
573	86	52
574	85	51
575	70	39
576	50	5
577	38	36
578	30	71
579	75	53
580	84	40
581	85	42
582	86	49
583	86	57
584	89	68
585	99	61



586	77	29
587	81	72
588	89	69
589	49	56

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
590	79	70
591	104	59
592	103	54
593	102	56
594	102	56
595	103	61
596	102	64
597	103	60
598	93	72
599	86	73
600	76	73
601	59	49
602	46	22
603	40	65
604	72	31
605	72	27
606	67	44
607	68	37
608	67	42
609	68	50
610	77	43
611	58	4

612	22	37
613	57	69
614	68	38
615	73	2

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
616	40	14
617	42	38
618	64	69
619	64	74
620	67	73
621	65	73
622	68	73
623	65	49
624	81	0
625	37	25
626	24	69
627	68	71
628	70	71
629	76	70
630	71	72
631	73	69
632	76	70
633	77	72
634	77	72
635	77	72
636	77	70
637	76	71

638	76	71
639	77	71
640	77	71
641	78	70

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
642	77	70
643	77	71
644	79	72
645	78	70
646	80	70
647	82	71
648	84	71
649	83	71
650	83	73
651	81	70
652	80	71
653	78	71
654	76	70
655	76	70
656	76	71
657	79	71
658	78	71
659	81	70
660	83	72
661	84	71
662	86	71
663	87	71

664	92	72
665	91	72
666	90	71
667	90	71

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
668	91	71
669	90	70
670	90	72
671	91	71
672	90	71
673	90	71
674	92	72
675	93	69
676	90	70
677	93	72
678	91	70
679	89	71
680	91	71
681	90	71
682	90	71
683	92	71
684	91	71
685	93	71
686	93	68
687	98	68
688	98	67
689	100	69

690	99	68
691	100	71
692	99	68
693	100	69

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
694	102	72
695	101	69
696	100	69
697	102	71
698	102	71
699	102	69
700	102	71
701	102	68
702	100	69
703	102	70
704	102	68
705	102	70
706	102	72
707	102	68
708	102	69
709	100	68
710	102	71
711	101	64
712	102	69
713	102	69
714	101	69
715	102	64

716	102	69
717	102	68
718	102	70
719	102	69

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
720	102	70
721	102	70
722	102	62
723	104	38
724	104	15
725	102	24
726	102	45
727	102	47
728	104	40
729	101	52
730	103	32
731	102	50
732	103	30
733	103	44
734	102	40
735	103	43
736	103	41
737	102	46
738	103	39
739	102	41
740	103	41
741	102	38

742	103	39
743	102	46
744	104	46
745	103	49

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
746	102	45
747	103	42
748	103	46
749	103	38
750	102	48
751	103	35
752	102	48
753	103	49
754	102	48
755	102	46
756	103	47
757	102	49
758	102	42
759	102	52
760	102	57
761	102	55
762	102	61
763	102	61
764	102	58
765	103	58
766	102	59
767	102	54

768	102	63
769	102	61
770	103	55
771	102	60

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
772	102	72
773	103	56
774	102	55
775	102	67
776	103	56
777	84	42
778	48	7
779	48	6
780	48	6
781	48	7
782	48	6
783	48	7
784	67	21
785	105	59
786	105	96
787	105	74
788	105	66
789	105	62
790	105	66
791	89	41
792	52	5
793	48	5

794	48	7
795	48	5
796	48	6
797	48	4

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
798	52	6
799	51	5
800	51	6
801	51	6
802	52	5
803	52	5
804	57	44
805	98	90
806	105	94
807	105	100
808	105	98
809	105	95
810	105	96
811	105	92
812	104	97
813	100	85
814	94	74
815	87	62
816	81	50
817	81	46
818	80	39
819	80	32

820	81	28
821	80	26
822	80	23
823	80	23

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
824	80	20
825	81	19
826	80	18
827	81	17
828	80	20
829	81	24
830	81	21
831	80	26
832	80	24
833	80	23
834	80	22
835	81	21
836	81	24
837	81	24
838	81	22
839	81	22
840	81	21
841	81	31
842	81	27
843	80	26
844	80	26
845	81	25

846	80	21
847	81	20
848	83	21
849	83	15

Time (s)	Normalized speed (%)	Normalized torque (%)
850	83	12
851	83	9
852	83	8
853	83	7
854	83	6
855	83	6
856	83	6
857	83	6
858	83	6
859	76	5
860	49	8
861	51	7
862	51	20
863	78	52
864	80	38
865	81	33
866	83	29
867	83	22
868	83	16
869	83	12
870	83	9
871	83	8

872	83	7
873	83	6
874	83	6
875	83	6

Time (s)	Normalized speed (%)	Normalized torque (%)
876	83	6
877	83	6
878	59	4
879	50	5
880	51	5
881	51	5
882	51	5
883	50	5
884	50	5
885	50	5
886	50	5
887	50	5
888	51	5
889	51	5
890	51	5
891	63	50
892	81	34
893	81	25
894	81	29
895	81	23
896	80	24
897	81	24



898	81	28
899	81	27
900	81	22
901	81	19

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
902	81	17
903	81	17
904	81	17
905	81	15
906	80	15
907	80	28
908	81	22
909	81	24
910	81	19
911	81	21
912	81	20
913	83	26
914	80	63
915	80	59
916	83	100
917	81	73
918	83	53
919	80	76
920	81	61
921	80	50
922	81	37
923	82	49

924	83	37
925	83	25
926	83	17
927	83	13

Time (s)	Normalized speed (%)	Normalized torque (%)
928	83	10
929	83	8
930	83	7
931	83	7
932	83	6
933	83	6
934	83	6
935	71	5
936	49	24
937	69	64
938	81	50
939	81	43
940	81	42
941	81	31
942	81	30
943	81	35
944	81	28
945	81	27
946	80	27
947	81	31
948	81	41
949	81	41

950	81	37
951	81	43
952	81	34
953	81	31

Time (s)	Normalized speed (%)	Normalized torque (%)
954	81	26
955	81	23
956	81	27
957	81	38
958	81	40
959	81	39
960	81	27
961	81	33
962	80	28
963	81	34
964	83	72
965	81	49
966	81	51
967	80	55
968	81	48
969	81	36
970	81	39
971	81	38
972	80	41
973	81	30
974	81	23
975	81	19

976	81	25
977	81	29
978	83	47
979	81	90

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
980	81	75
981	80	60
982	81	48
983	81	41
984	81	30
985	80	24
986	81	20
987	81	21
988	81	29
989	81	29
990	81	27
991	81	23
992	81	25
993	81	26
994	81	22
995	81	20
996	81	17
997	81	23
998	83	65
999	81	54
1000	81	50
1001	81	41

1002	81	35
1003	81	37
1004	81	29
1005	81	28

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1006	81	24
1007	81	19
1008	81	16
1009	80	16
1010	83	23
1011	83	17
1012	83	13
1013	83	27
1014	81	58
1015	81	60
1016	81	46
1017	80	41
1018	80	36
1019	81	26
1020	86	18
1021	82	35
1022	79	53
1023	82	30
1024	83	29
1025	83	32
1026	83	28
1027	76	60

1028	79	51
1029	86	26
1030	82	34
1031	84	25

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1032	86	23
1033	85	22
1034	83	26
1035	83	25
1036	83	37
1037	84	14
1038	83	39
1039	76	70
1040	78	81
1041	75	71
1042	86	47
1043	83	35
1044	81	43
1045	81	41
1046	79	46
1047	80	44
1048	84	20
1049	79	31
1050	87	29
1051	82	49
1052	84	21
1053	82	56

1054	81	30
1055	85	21
1056	86	16
1057	79	52

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1058	78	60
1059	74	55
1060	78	84
1061	80	54
1062	80	35
1063	82	24
1064	83	43
1065	79	49
1066	83	50
1067	86	12
1068	64	14
1069	24	14
1070	49	21
1071	77	48
1072	103	11
1073	98	48
1074	101	34
1075	99	39
1076	103	11
1077	103	19
1078	103	7
1079	103	13

1080	103	10
1081	102	13
1082	101	29
1083	102	25

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1084	102	20
1085	96	60
1086	99	38
1087	102	24
1088	100	31
1089	100	28
1090	98	3
1091	102	26
1092	95	64
1093	102	23
1094	102	25
1095	98	42
1096	93	68
1097	101	25
1098	95	64
1099	101	35
1100	94	59
1101	97	37
1102	97	60
1103	93	98
1104	98	53
1105	103	13

1106	103	11
1107	103	11
1108	103	13
1109	103	10

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1110	103	10
1111	103	11
1112	103	10
1113	103	10
1114	102	18
1115	102	31
1116	101	24
1117	102	19
1118	103	10
1119	102	12
1120	99	56
1121	96	59
1122	74	28
1123	66	62
1124	74	29
1125	64	74
1126	69	40
1127	76	2
1128	72	29
1129	66	65
1130	54	69
1131	69	56

1132	69	40
1133	73	54
1134	63	92
1135	61	67

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1136	72	42
1137	78	2
1138	76	34
1139	67	80
1140	70	67
1141	53	70
1142	72	65
1143	60	57
1144	74	29
1145	69	31
1146	76	1
1147	74	22
1148	72	52
1149	62	96
1150	54	72
1151	72	28
1152	72	35
1153	64	68
1154	74	27
1155	76	14
1156	69	38
1157	66	59

1158	64	99
1159	51	86
1160	70	53
1161	72	36

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1162	71	47
1163	70	42
1164	67	34
1165	74	2
1166	75	21
1167	74	15
1168	75	13
1169	76	10
1170	75	13
1171	75	10
1172	75	7
1173	75	13
1174	76	8
1175	76	7
1176	67	45
1177	75	13
1178	75	12
1179	73	21
1180	68	46
1181	74	8
1182	76	11
1183	76	14

1184	74	11
1185	74	18
1186	73	22
1187	74	20

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1188	74	19
1189	70	22
1190	71	23
1191	73	19
1192	73	19
1193	72	20
1194	64	60
1195	70	39
1196	66	56
1197	68	64
1198	30	68
1199	70	38
1200	66	47
1201	76	14
1202	74	18
1203	69	46
1204	68	62
1205	68	62
1206	68	62
1207	68	62
1208	68	62
1209	68	62



1210	54	50
1211	41	37
1212	27	25
1213	14	12

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1214	0	0
1215	0	0
1216	0	0
1217	0	0
1218	0	0
1219	0	0
1220	0	0
1221	0	0
1222	0	0
1223	0	0
1224	0	0
1225	0	0
1226	0	0
1227	0	0
1228	0	0
1229	0	0
1230	0	0
1231	0	0
1232	0	0
1233	0	0
1234	0	0
1235	0	0

1236	0	0
1237	0	0
1238	0	0

## LSI-NRTC engine dynamometer schedule

Time (s)	Normalized speed (%)	Normalized torque (%)
0	0	0
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	0	0
7	0	0
8	0	0
9	1	8
10	6	54
11	8	61
12	34	59
13	22	46
14	5	51
15	18	51
16	31	50
17	30	56
18	31	49
19	25	66
20	58	55

21	43	31
22	16	45
23	24	38

Time (s)	Normalized speed (%)	Normalized torque (%)
24	24	27
25	30	33
26	45	65
27	50	49
28	23	42
29	13	42
30	9	45
31	23	30
32	37	45
33	44	50
34	49	52
35	55	49
36	61	46
37	66	38
38	42	33
39	17	41
40	17	37
41	7	50
42	20	32
43	5	55
44	30	42

45	44	53
46	45	56
47	41	52

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
48	24	41
49	15	40
50	11	44
51	32	31
52	38	54
53	38	47
54	9	55
55	10	50
56	33	55
57	48	56
58	49	47
59	33	44
60	52	43
61	55	43
62	59	38
63	44	28
64	24	37
65	12	44
66	9	47
67	12	52
68	34	21

69	29	44
70	44	54
71	54	62

Time (s)	Normalized speed (%)	Normalized torque (%)
72	62	57
73	72	56
74	88	71
75	100	69
76	100	34
77	100	42
78	100	54
79	100	58
80	100	38
81	83	17
82	61	15
83	43	22
84	24	35
85	16	39
86	15	45
87	32	34
88	14	42
89	8	48
90	5	51
91	10	41
92	12	37

93	4	47
94	3	49
95	3	50
96	4	49
97	4	48

Time (s)	Normalized speed (%)	Normalized torque (%)
98	8	43
99	2	51
100	5	46
101	8	41
102	4	47
103	3	49
104	6	45
105	3	48
106	10	42
107	18	27
108	3	50
109	11	41
110	34	29
111	51	57
112	67	63
113	61	32
114	44	31
115	48	54
116	69	65
117	85	65
118	81	29

119	74	21
120	62	23
121	76	58
122	96	75
123	100	77

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
124	100	27
125	100	79
126	100	79
127	100	81
128	100	57
129	99	52
130	81	35
131	69	29
132	47	22
133	34	28
134	27	37
135	83	60
136	100	74
137	100	7
138	100	2
139	70	18
140	23	39
141	5	54
142	11	40
143	11	34
144	11	41

145	19	25
146	16	32
147	20	31
148	21	38
149	21	42

Time (s)	Normalized speed (%)	Normalized torque (%)
150	9	51
151	4	49
152	2	51
153	1	58
154	21	57
155	29	47
156	33	45
157	16	49
158	38	45
159	37	43
160	35	42
161	39	43
162	51	49
163	59	55
164	65	54
165	76	62
166	84	59
167	83	29
168	67	35
169	84	54
170	90	58

171	93	43
172	90	29
173	66	19
174	52	16
175	49	17

Time (s)	Normalized speed (%)	Normalized torque (%)
176	56	38
177	73	71
178	86	80
179	96	75
180	89	27
181	66	17
182	50	18
183	36	25
184	36	24
185	38	40
186	40	50
187	27	48
188	19	48
189	23	50
190	19	45
191	6	51
192	24	48
193	49	67
194	47	49
195	22	44
196	25	40

197	38	54
198	43	55
199	40	52
200	14	49
201	11	45

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
202	7	48
203	26	41
204	41	59
205	53	60
206	44	54
207	22	40
208	24	41
209	32	53
210	44	74
211	57	25
212	22	49
213	29	45
214	19	37
215	14	43
216	36	40
217	43	63
218	42	49
219	15	50
220	19	44
221	47	59
222	67	80

223	76	74
224	87	66
225	98	61
226	100	38
227	97	27



<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
228	100	53
229	100	72
230	100	49
231	100	4
232	100	13
233	87	15
234	53	26
235	33	27
236	39	19
237	51	33
238	67	54
239	83	60
240	95	52
241	100	50
242	100	36
243	100	25
244	85	16
245	62	16
246	40	26
247	56	39
248	81	75

249	98	86
250	100	76
251	100	51
252	100	78
253	100	83

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
254	100	100
255	100	66
256	100	85
257	100	72
258	100	45
259	98	58
260	60	30
261	43	32
262	71	36
263	44	32
264	24	38
265	42	17
266	22	51
267	13	53
268	23	45
269	29	50
270	28	42
271	21	55
272	34	57
273	44	47
274	19	46

275	13	44
276	25	36
277	43	51
278	55	73
279	68	72

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
280	76	63
281	80	45
282	83	40
283	78	26
284	60	20
285	47	19
286	52	25
287	36	30
288	40	26
289	45	34
290	47	35
291	42	28
292	46	38
293	48	44
294	68	61
295	70	47
296	48	28
297	42	22
298	31	29
299	22	35
300	28	28

301	46	46
302	62	69
303	76	81
304	88	85
305	98	81

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
306	100	74
307	100	13
308	100	11
309	100	17
310	99	3
311	80	7
312	62	11
313	63	11
314	64	16
315	69	43
316	81	67
317	93	74
318	100	72
319	94	27
320	73	15
321	40	33
322	40	52
323	50	50
324	11	53
325	12	45
326	5	50

327	1	55
328	7	55
329	62	60
330	80	28
331	23	37

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
332	39	58
333	47	24
334	59	51
335	58	68
336	36	52
337	18	42
338	36	52
339	59	73
340	72	85
341	85	92
342	99	90
343	100	72
344	100	18
345	100	76
346	100	64
347	100	87
348	100	97
349	100	84
350	100	100
351	100	91
352	100	83

353	100	93
354	100	100
355	94	43
356	72	10
357	77	3

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
358	48	2
359	29	5
360	59	19
361	63	5
362	35	2
363	24	3
364	28	2
365	36	16
366	54	23
367	60	10
368	33	1
369	23	0
370	16	0
371	11	0
372	20	0
373	25	2
374	40	3
375	33	4
376	34	5
377	46	7
378	57	10

379	66	11
380	75	14
381	79	11
382	80	16
383	92	21

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
384	99	16
385	83	2
386	71	2
387	69	4
388	67	4
389	74	16
390	86	25
391	97	28
392	100	15
393	83	2
394	62	4
395	40	6
396	49	10
397	36	5
398	27	4
399	29	3
400	22	2
401	13	3
402	37	36
403	90	26
404	41	2

405	25	2
406	29	2
407	38	7
408	50	13
409	55	10

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
410	29	3
411	24	7
412	51	16
413	62	15
414	72	35
415	91	74
416	100	73
417	100	8
418	98	11
419	100	59
420	100	98
421	100	99
422	100	75
423	100	95
424	100	100
425	100	97
426	100	90
427	100	86
428	100	82
429	97	43
430	70	16

431	50	20
432	42	33
433	89	64
434	89	77
435	99	95

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
436	100	41
437	77	12
438	29	37
439	16	41
440	16	38
441	15	36
442	18	44
443	4	55
444	24	26
445	26	35
446	15	45
447	21	39
448	29	52
449	26	46
450	27	50
451	13	43
452	25	36
453	37	57
454	29	46
455	17	39
456	13	41

457	19	38
458	28	35
459	8	51
460	14	36
461	17	47

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
462	34	39
463	34	57
464	11	70
465	13	51
466	13	68
467	38	44
468	53	67
469	29	69
470	19	65
471	52	45
472	61	79
473	29	70
474	15	53
475	15	60
476	52	40
477	50	61
478	13	74
479	46	51
480	60	73
481	33	84
482	31	63

483	41	42
484	26	69
485	23	65
486	48	49
487	28	57

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
488	16	67
489	39	48
490	47	73
491	35	87
492	26	73
493	30	61
494	34	49
495	35	66
496	56	47
497	49	64
498	59	64
499	42	69
500	6	77
501	5	59
502	17	59
503	45	53
504	21	62
505	31	60
506	53	68
507	48	79
508	45	61

509	51	47
510	41	48
511	26	58
512	21	62
513	50	52

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
514	39	65
515	23	65
516	42	62
517	57	80
518	66	81
519	64	62
520	45	42
521	33	42
522	27	57
523	31	59
524	41	53
525	45	72
526	48	73
527	46	90
528	56	76
529	64	76
530	69	64
531	72	59
532	73	58
533	71	56
534	66	48

535	61	50
536	55	56
537	52	52
538	54	49
539	61	50



<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
540	64	54
541	67	54
542	68	52
543	60	53
544	52	50
545	45	49
546	38	45
547	32	45
548	26	53
549	23	56
550	30	49
551	33	55
552	35	59
553	33	65
554	30	67
555	28	59
556	25	58
557	23	56
558	22	57
559	19	63
560	14	63

561	31	61
562	35	62
563	21	80
564	28	65
565	7	74

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
566	23	54
567	38	54
568	14	78
569	38	58
570	52	75
571	59	81
572	66	69
573	54	44
574	48	34
575	44	33
576	40	40
577	28	58
578	27	63
579	35	45
580	20	66
581	15	60
582	10	52
583	22	56
584	30	62
585	21	67
586	29	53

587	41	56
588	15	67
589	24	56
590	42	69
591	39	83

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
592	40	73
593	35	67
594	32	61
595	30	65
596	30	72
597	48	51
598	66	58
599	62	71
600	36	63
601	17	59
602	16	50
603	16	62
604	34	48
605	51	66
606	35	74
607	15	56
608	19	54
609	43	65
610	52	80
611	52	83
612	49	57

613	48	46
614	37	36
615	25	44
616	14	53
617	13	64

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
618	23	56
619	21	63
620	18	67
621	20	54
622	16	67
623	26	56
624	41	65
625	28	62
626	19	60
627	33	56
628	37	70
629	24	79
630	28	57
631	40	57
632	40	58
633	28	44
634	25	41
635	29	53
636	31	55
637	26	64
638	20	50

639	16	53
640	11	54
641	13	53
642	23	50
643	32	59

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
644	36	63
645	33	59
646	24	52
647	20	52
648	22	55
649	30	53
650	37	59
651	41	58
652	36	54
653	29	49
654	24	53
655	14	57
656	10	54
657	9	55
658	10	57
659	13	55
660	15	64
661	31	57
662	19	69
663	14	59
664	33	57

665	41	65
666	39	64
667	39	59
668	39	51
669	28	41

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
670	19	49
671	27	54
672	37	63
673	32	74
674	16	70
675	12	67
676	13	60
677	17	56
678	15	62
679	25	47
680	27	64
681	14	71
682	5	65
683	6	57
684	6	57
685	15	52
686	22	61
687	14	77
688	12	67
689	12	62
690	14	59

691	15	58
692	18	55
693	22	53
694	19	69
695	14	67

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
696	9	63
697	8	56
698	17	49
699	25	55
700	14	70
701	12	60
702	22	57
703	27	67
704	29	68
705	34	62
706	35	61
707	28	78
708	11	71
709	4	58
710	5	58
711	10	56
712	20	63
713	13	76
714	11	65
715	9	60
716	7	55

717	8	53
718	10	60
719	28	53
720	12	73
721	4	64

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
722	4	61
723	4	61
724	10	56
725	8	61
726	20	56
727	32	62
728	33	66
729	34	73
730	31	61
731	33	55
732	33	60
733	31	59
734	29	58
735	31	53
736	33	51
737	33	48
738	27	44
739	21	52
740	13	57
741	12	56
742	10	64

743	22	47
744	15	74
745	8	66
746	34	47
747	18	71

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
748	9	57
749	11	55
750	12	57
751	10	61
752	16	53
753	12	75
754	6	70
755	12	55
756	24	50
757	28	60
758	28	64
759	23	60
760	20	56
761	26	50
762	28	55
763	18	56
764	15	52
765	11	59
766	16	59
767	34	54
768	16	82

769	15	64
770	36	53
771	45	64
772	41	59
773	34	50

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
774	27	45
775	22	52
776	18	55
777	26	54
778	39	62
779	37	71
780	32	58
781	24	48
782	14	59
783	7	59
784	7	55
785	18	49
786	40	62
787	44	73
788	41	68
789	35	48
790	29	54
791	22	69
792	46	53
793	59	71
794	69	68

795	75	47
796	62	32
797	48	35
798	27	59
799	13	58

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
800	14	54
801	21	53
802	23	56
803	23	57
804	23	65
805	13	65
806	9	64
807	27	56
808	26	78
809	40	61
810	35	76
811	28	66
812	23	57
813	16	50
814	11	53
815	9	57
816	9	62
817	27	57
818	42	69
819	47	75
820	53	67

821	61	62
822	63	53
823	60	54
824	56	44
825	49	39

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
826	39	35
827	30	34
828	33	46
829	44	56
830	50	56
831	44	52
832	38	46
833	33	44
834	29	45
835	24	46
836	18	52
837	9	55
838	10	54
839	20	53
840	27	58
841	29	59
842	30	62
843	30	65
844	27	66
845	32	58
846	40	56

847	41	57
848	18	73
849	15	55
850	18	50
851	17	52



<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
852	20	49
853	16	62
854	4	67
855	2	64
856	7	54
857	10	50
858	9	57
859	5	62
860	12	51
861	14	65
862	9	64
863	31	50
864	30	78
865	21	65
866	14	51
867	10	55
868	6	59
869	7	59
870	19	54
871	23	61
872	24	62

873	34	61
874	51	67
875	60	66
876	58	55
877	60	52

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
878	64	55
879	68	51
880	63	54
881	64	50
882	68	58
883	73	47
884	63	40
885	50	38
886	29	61
887	14	61
888	14	53
889	42	6
890	58	6
891	58	6
892	77	39
893	93	56
894	93	44
895	93	37
896	93	31
897	93	25
898	93	26

899	93	27
900	93	25
901	93	21
902	93	22
903	93	24

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
904	93	23
905	93	27
906	93	34
907	93	32
908	93	26
909	93	31
910	93	34
911	93	31
912	93	33
913	93	36
914	93	37
915	93	34
916	93	30
917	93	32
918	93	35
919	93	35
920	93	32
921	93	28
922	93	23
923	94	18
924	95	18

925	96	17
926	95	13
927	96	10
928	95	9
929	95	7

Time (s)	Normalized speed (%)	Normalized torque (%)
930	95	7
931	96	7
932	96	6
933	96	6
934	95	6
935	90	6
936	69	43
937	76	62
938	93	47
939	93	39
940	93	35
941	93	34
942	93	36
943	93	39
944	93	34
945	93	26
946	93	23
947	93	24
948	93	24
949	93	22
950	93	19

951	93	17
952	93	19
953	93	22
954	93	24
955	93	23

Time (s)	Normalized speed (%)	Normalized torque (%)
956	93	20
957	93	20
958	94	19
959	95	19
960	95	17
961	96	13
962	95	10
963	96	9
964	95	7
965	95	7
966	95	7
967	95	6
968	96	6
969	96	6
970	89	6
971	68	6
972	57	6
973	66	32
974	84	52
975	93	46
976	93	42

977	93	36
978	93	28
979	93	23
980	93	19
981	93	16

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
982	93	15
983	93	16
984	93	15
985	93	14
986	93	15
987	93	16
988	94	15
989	93	32
990	93	45
991	93	43
992	93	37
993	93	29
994	93	23
995	93	20
996	93	18
997	93	16
998	93	17
999	93	16
1000	93	15
1001	93	15
1002	93	15

1003	93	14
1004	93	15
1005	93	15
1006	93	14
1007	93	13

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1008	93	14
1009	93	14
1010	93	15
1011	93	16
1012	93	17
1013	93	20
1014	93	22
1015	93	20
1016	93	19
1017	93	20
1018	93	19
1019	93	19
1020	93	20
1021	93	32
1022	93	37
1023	93	28
1024	93	26
1025	93	24
1026	93	22
1027	93	22
1028	93	21

1029	93	20
1030	93	20
1031	93	20
1032	93	20
1033	93	19

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1034	93	18
1035	93	20
1036	93	20
1037	93	20
1038	93	20
1039	93	19
1040	93	18
1041	93	18
1042	93	17
1043	93	16
1044	93	16
1045	93	15
1046	93	16
1047	93	18
1048	93	37
1049	93	48
1050	93	38
1051	93	31
1052	93	26
1053	93	21
1054	93	18

1055	93	16
1056	93	17
1057	93	18
1058	93	19
1059	93	21

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1060	93	20
1061	93	18
1062	93	17
1063	93	17
1064	93	18
1065	93	18
1066	93	18
1067	93	19
1068	93	18
1069	93	18
1070	93	20
1071	93	23
1072	93	25
1073	93	25
1074	93	24
1075	93	24
1076	93	22
1077	93	22
1078	93	22
1079	93	19
1080	93	16

1081	95	17
1082	95	37
1083	93	43
1084	93	32
1085	93	27

Time (s)	Normalized speed (%)	Normalized torque (%)
1086	93	26
1087	93	24
1088	93	22
1089	93	22
1090	93	22
1091	93	23
1092	93	22
1093	93	22
1094	93	23
1095	93	23
1096	93	23
1097	93	22
1098	93	23
1099	93	23
1100	93	23
1101	93	25
1102	93	27
1103	93	26
1104	93	25
1105	93	27
1106	93	27

1107	93	27
1108	93	24
1109	93	20
1110	93	18
1111	93	17

Time (s)	Normalized speed (%)	Normalized torque (%)
1112	93	17
1113	93	18
1114	93	18
1115	93	18
1116	93	19
1117	93	22
1118	93	22
1119	93	19
1120	93	17
1121	93	17
1122	93	18
1123	93	18
1124	93	19
1125	93	19
1126	93	20
1127	93	19
1128	93	20
1129	93	25
1130	93	30
1131	93	31
1132	93	26

1133	93	21
1134	93	18
1135	93	20
1136	93	25
1137	93	24

<b>Time (s)</b>	<b>Normalized speed (%)</b>	<b>Normalized torque (%)</b>
1138	93	21
1139	93	21
1140	93	22
1141	93	22
1142	93	28
1143	93	29
1144	93	23
1145	93	21
1146	93	18
1147	93	16
1148	93	16
1149	93	16
1150	93	17
1151	93	17
1152	93	17
1153	93	17
1154	93	23
1155	93	26
1156	93	22
1157	93	18
1158	93	16

1159	93	16
1160	93	17
1161	93	19
1162	93	18
1163	93	16



Time (s)	Normalized speed (%)	Normalized torque (%)
1164	93	19
1165	93	22
1166	93	25
1167	93	29
1168	93	27
1169	93	22
1170	93	18
1171	93	16
1172	93	19
1173	93	19
1174	93	17
1175	93	17
1176	93	17
1177	93	16
1178	93	16
1179	93	15
1180	93	16
1181	93	15
1182	93	17
1183	93	21
1184	93	30

1185	93	53
1186	93	54
1187	93	38
1188	93	30
1189	93	24

Time (s)	Normalized speed (%)	Normalized torque (%)
1190	93	20
1191	95	20
1192	96	18
1193	96	15
1194	96	11
1195	95	9
1196	95	8
1197	96	7
1198	94	33
1199	93	46
1200	93	37
1201	16	8
1202	0	0
1203	0	0
1204	0	0
1205	0	0
1206	0	0
1207	0	0
1208	0	0
1209	0	0

