

Transmitted by the chairman of the GFV Group

PROPOSAL FOR A DRAFT SUPPLEMENT TO  
 the 5<sup>th</sup> series of amendments to REGULATION No. 49 (rev.5)

The text reproduced below was prepared by the experts from the informal HDDF Task Force within the GFV informal working group in order to enable the type approval of new EURO V heavy duty dual-fuel engines and vehicles

**General remarks**

The major points that will have to be addressed after GRPE65 are:

- The possible introduction of an Annex 4D, that is mainly a copy and paste from Annex 4 on rev.6 of R49
- The modifications of the details of the administrative information to be provided at type-approval
- GER (Gas Energy Ratio) test at certification in case of Type2 dual-fuel engines

**A. PROPOSAL**

**A1. Modifications to section 1 (scope)**

*Paragraph 1.1., Table A, amend to read (also inserting new footnote):*

**Table A**  
**Applicability**

Vehicle category <sup>1</sup>	Positive-ignition engines			Dual-fuel engines	Compression-ignition engines	
	Petrol	NG <sup>a</sup>	LPG <sup>b</sup>		Diesel	Ethanol
M <sub>1</sub>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>	R49 <sup>d</sup>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>
M <sub>2</sub>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>		R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>
M <sub>3</sub>	R49	R49	R49		R49	R49
N <sub>1</sub>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>		R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>
N <sub>2</sub>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>		R49 or R83 <sup>c</sup>	R49 or R83 <sup>c</sup>
N <sub>3</sub>	R49	R49	R49		R49	R49

<sup>a</sup> Natural Gas

<sup>b</sup> Liquefied Petroleum Gas

<sup>c</sup> Regulation No. 83 applies for vehicles with a reference mass ≤ 2,610 kg and by extension of an approval for vehicles with a reference mass ≤ 2,840 kg

<sup>d</sup> The provisions related to dual-fuel engines and vehicles contained into Regulation No. 49 only apply for vehicles and engines within the scope of rev.5 of that Regulation

Paragraph 1.1., Table B, amend to read (also inserting new footnote):

**Table B**  
**Requirements**

	Positive-ignition engines			Dual-fuel Engines <sup>3</sup>	Compression-ignition engines	
	Petrol	NG	LPG		Diesel	Ethanol
Gaseous pollutants	-	Yes	Yes	Yes	Yes	Yes
Particulates	-	Yes <sup>a</sup>	Yes <sup>a</sup>	Yes	Yes	Yes
Smoke	-	-	-	Yes	Yes	Yes
Durability	-	Yes	Yes	Yes	Yes	Yes
In-service-conformity	-	Yes	Yes	Yes	Yes	Yes
OBD	-	Yes <sup>b</sup>	Yes <sup>b</sup>	Yes	Yes	Yes

<sup>a</sup> Only applicable to stage C in Table 2 of paragraph 5.2.1.

<sup>b</sup> Application dates according to paragraph 5.4.2.

<sup>3</sup> According to the requirements of Annex 11

Insert new paragraphs 1.2.1., to read:

- 1.2.1. Equivalent approval as set out in paragraph 1.2. shall not be granted in the case of dual-fuel engines and vehicles (see definitions in section 2 of this Regulation).

## A2. Modifications to section 2.1 (definitions)

Paragraphs 2.1.15. (former) to 2.1.35 (former)., renumber as paragraphs 2.1.20. to 2.1.40.

Paragraphs 2.1.36. (former) to 2.1.56 (former)., renumber as paragraphs 2.1.42. to 2.1.62.

Paragraphs 2.1.57. (former) to 2.1.66 (former)., renumber as paragraphs 2.1.64. to 2.1.73.

Insert new paragraphs 2.1.15., to read:

- 2.1.15. "Diesel mode" means the normal operating mode of a dual-fuel engine during which the engine does not use any gaseous fuel for any engine operating condition.

Insert a new paragraph 2.1.16., to read:

2.1.16. "Driving cycle"  
means a sequence consisting of an engine start, an operating period (of the vehicle), an engine shut-off, and the time until the next engine start;

*Insert new paragraphs 2.1.17., to read:*

2.1.17. "Dual-fuel engine" means an engine system that is designed to simultaneously operate with diesel fuel and a gaseous fuel, both fuels being metered separately, where the consumed amount of one of the fuels relative to the other one may vary depending on the operation.

*Insert new paragraphs 2.1.18., to read:*

2.1.18 "Dual-fuel mode" means the normal operating mode of a dual-fuel engine during which the engine simultaneously uses diesel fuel and a gaseous fuel at some engine operating conditions.

*Insert new paragraphs 2.1.19., to read:*

2.1.19 "Dual-fuel vehicle" means a vehicle that is powered by a dual-fuel engine and that supplies the fuels used by the engine from separate on-board storage systems.

*Insert new paragraphs 2.1.41., to read:*

2.1.41 LNG<sub>20</sub> means a specific liquefied natural gas / liquefied biomethane composition resulting in a  $\lambda$ -shift factor not differing by more than 3 per cent the  $\lambda$ -shift factor of the G<sub>20</sub> gas specified in Annex 5, and the ethane content of which does not exceed 1.5 per cent

*Insert new paragraphs 2.1.63., to read:*

2.1.63. "Service mode" means a special mode of a dual-fuel engine that is activated for the purpose of repairing, or of moving the vehicle from the traffic when operation in the dual-fuel mode is not possible.

### **A3. Modifications to section 4 (approval)**

*Paragraph 4.1.1.*, amend to read:

"4.1.1. In the case of diesel, ethanol, or LNG<sub>20</sub> fuel the parent engine meets the requirements of this Regulation on the reference fuel specified in Annex 5.

*Insert a new paragraph 4.1.1.1.*, to read:

4.1.1.1. In the case of a dual-fuel engine family the parent engine meets in addition the requirements set out in Annex 11 on the reference fuels specified in Annex 5

*Paragraph 4.1.2.*, 1st sentence, amend to read:

4.1.2. In the case of compressed natural gas the parent engine, including in the case of a dual-fuel engine family, should demonstrate its capability to adapt to any fuel composition that may occur across the market.

*Paragraph 4.1.3.*, 1st sentence, amend to read:

4.1.3. In the case of an engine, including a dual-fuel engine, fuelled with compressed natural gas which is self-adaptive for the range of H-gases on the one hand and the range of L-gases on the other hand, and which switches between the H-range and the L-range by means of a switch, the parent engine shall be tested on the relevant reference fuel as specified in Annex 5 for each range, at each position of the switch.

*Paragraph 4.1.4.*, 1st sentence, amend to read:

4.1.4. In the case of compressed natural gas engines, including dual-fuel engines, the ratio of the emission results "r" shall be determined for each pollutant as follows:

*Paragraph 4.1.5.*, 1st sentence, amend to read:

- 4.1.5. In the case of LPG the parent engine, including in the case of a dual-fuel engine family, should demonstrate its capability to adapt to any fuel composition that may occur across the market.

*Insert a new paragraph 4.1.6.*, to read:

- 4.1.6. In the case of liquefied natural gas/biomethane (LNG) the parent engine, including in the case of a dual-fuel engine family, shall meet the requirements of this Regulation on the reference fuels  $G_R$  (fuel 1) and  $G_{20}$  (fuel 2), as specified in Annex 5, without any manual readjustment to the engine fuelling system between the two tests (self adaptation is required). One adaptation run over one ETC cycle without measurement is permitted after the change of the fuel.

*Paragraph 4.2.1.*, title and 1st sentence, amend to read:

- 4.2.1. *Exhaust emissions approval of an engine running on compressed natural gas and laid out for operation on either the range of H-gases or on the range of L-gases*

The parent engines shall be tested on the relevant reference fuels, as specified in Annex 5, for the relevant range.

Note: This also applies in the case of a dual-fuel engine

*Paragraph 4.2.2.*, title, amend to read:

- 4.2.2. *Exhaust emissions approval of an engine running on compressed natural gas or LPG and laid out for operation on one specific fuel composition*

*Paragraph 4.2.2.1.*, 1st sentence, amend to read:

- 4.2.2.1. The parent engine shall meet the emission requirements on the reference fuels  $G_R$  and  $G_{25}$  in the case of compressed natural gas, or the reference fuels A and B in the case of LPG, as specified in Annex 5.

Note: This also applies in the case of a dual-fuel engine

*Insert a new paragraph 4.2.3.*, to read:

- 4.2.3. In the case of a dual-fuel engine family the parent engine shall meet in addition the requirements set out in Annex 11 on the reference fuels specified in Annex 5

*Section 4.2., first table, title, amend to read*

Approval of compressed NG-fuelled engines

*Insert a new paragraph 4.6.3.1.7.*, to read:

- 4.6.3.1.7. LNG<sub>20</sub> in case of the engine being approved and calibrated for a specific LNG composition resulting in a  $\lambda$ -shift factor not differing by more than 3 per cent the  $\lambda$ -shift factor of the G20 gas specified in Annex IX, and the ethane content of which does not exceed 1.5 per cent.

*Insert a new paragraph 4.6.3.1.8.*, to read:

- 4.6.3.1.8. LNG in case of the engine being approved and calibrated for any other LNG composition

*Insert a new paragraph 4.6.3.2.*, to read:

- 4.6.3.2. For dual-fuel engines, the approval mark shall contain a series of digits after the national symbol, the purpose of which is to distinguish for which dual-fuel engine type and with which range of gases the approval has been granted. The series of digits will be constituted of two digits for the dual-fuel engine Type defined in Annex 11, followed by the letter(s) specified in paragraph 4.6.3.1. The two digits identifying the dual-fuel engine Types defined in Annex 11 are the following:

- (i) 1A for dual-fuel engines of Type 1A;
- (ii) 1B for dual-fuel engines of Type 1B;
- (iii) 2B for dual-fuel engines of Type 2B;
- (iv) 3B for dual-fuel engines of Type 3B.

*Paragraph 4.11.*, amend to read:

In the case of compressed NG and LPG fuelled engines with a fuel range restricted type approval, and in the case of LNG<sub>20</sub> engines, the following labels are applicable, including in the case of dual-fuel engines:

*Paragraph 4.11.1.*, add a new sentence after the first one, to read:

The following information shall be given:

In the case of an engine fuelled with LNG<sub>20</sub>., the label shall state "ONLY FOR USE WITH LNG<sub>20</sub>".

#### **A4. Modifications to section 5 (specifications and tests)**

*Insert new paragraphs 5.6. and 5.6.1.*, to read:

- 5.6. Requirements related to dual-fuel engines and vehicles
- 5.6.1 Dual-fuel engine and vehicles shall in addition meet the requirements set out in Annex 11 to this Regulation. These requirements shall have precedence over those set out in paragraphs 5.1 to 5.5 of this Regulation

#### **A5. Modifications to section 6 (installation on the vehicle)**

*Insert new paragraphs 6.2. and 6.2.1.*, to read:

- 6.2 Requirements related to dual-fuel engines and vehicles
- 6.2.1 Notwithstanding the requirements set out in paragraphs 6.1 of this Regulation, dual-fuel engines and vehicles shall in addition meet the requirements set out in Annex 11 to this Regulation

#### **A6. Modifications to section 8 (conformity of production)**

*Paragraph 8.3.1.1.*, amend to read:

- 8.3.1.1. Three engines are randomly taken in the series. Engines that are subject to testing only on the ESC and ELR tests or only on the ETC test for type approval to row A of the tables in paragraph 5.2.1. are subject to those applicable tests for the checking of production conformity. With the agreement of the authority, all other engines type approved to row A, B1 or B2, or C of the tables in paragraph 5.2.1. are subjected to testing either on the ESC and ELR cycles or on the ETC cycle for the checking of the production conformity. The limit values are given in paragraph 5.2.1. of this Regulation, or, in the case of a dual-fuel engine in Annex 11 of this Regulation..

*Insert a new paragraphs 8.3.1.1.1.*, to read:

- 8.3.1.1.1. Dual-fuel engines are tested in dual-fuel mode. When a diesel mode is available, dual-fuel engines shall also be tested in diesel mode. In that case, the test shall be performed just before or just after the test in dual-

fuel mode, on the same engine, on the same engine test-bed, and under the same laboratory conditions.

*Paragraph 8.3.1.3., amend to read:*

8.3.1.3. On the basis of a test of the engine by sampling, the production of a series is regarded as conforming where a pass decision is reached for all the pollutants and non conforming where a fail decision is reached for one pollutant, in accordance with the test criteria applied in the appropriate Appendix.

In the case of dual-fuel engines tested both in dual-fuel and diesel mode, the production of a series is regarded as conforming where a pass decision is reached for all the pollutants in both dual-fuel and diesel modes and non conforming where a fail decision is reached for one pollutant in either of the operating modes.

When a pass decision has been reached for one pollutant, this decision may not be changed by any additional tests made in order to reach a decision for the other pollutants.

If no pass decision is reached for all the pollutants and if no fail decision is reached for one pollutant, a test is carried out on another engine (see Figure 2).

If no decision is reached, the manufacturer may at any time decide to stop testing. In that case a fail decision is recorded.

*Insert a new paragraphs 8.3.2.5.1., to read:*

In the case of dispute caused by the non-compliance of engines approved for operating on LNG<sub>20</sub>, including dual-fuel engines, when using a market fuel, the tests shall be performed with G<sub>20</sub>, as specified in Annex 5.

**A7. Modifications to Annexes 1 to 3 and appendices (information / type-approval documents)**

[To be documented]

**A8. Introduction of a new Annex 4D**

[To be copied from Annex 4 of rev.6

Note: the tables for the u-gas values etc. may need to be adapted to Euro V reference fuels.]

**A9. Introduction of a new Annex 11**

A new Annex 11 is introduced, to read:

**Annex 11**

**TECHNICAL REQUIREMENTS FOR DUAL-FUEL ENGINES AND VEHICLES**

**1. SCOPE**

This annex shall apply to dual fuel engines and vehicles. Per definition these engines and vehicles are fuelled with diesel and a gaseous fuel.

Notwithstanding the provisions regarding multi-setting engines set-out in section 5.1.2.1. of this Regulation, dual-fuel and service modes as described in this Annex are permitted.

**2. DEFINITIONS AND ABBREVIATIONS**

**2.1. "Gas Energy Ratio (GER)"**

means in case of a dual-fuel engine, the ratio of the energy content of the gaseous fuel divided by the energy content of both fuels (diesel and gaseous), expressed as a percentage, the energy content of the fuels being defined as the lower heating value, .

**2.2. "Average gas ratio"**

means the average Gas Energy Ratio calculated over a driving cycle.

**2.3. " Type 1A dual-fuel engine"**

means a dual-fuel engine that operates over the ETC test-cycle with an average gas ratio that is not lower than 90 per cent ( $GER_{ETC} \geq 90 \%$ ), and that does not idle using exclusively diesel fuel, and that has no diesel mode.

- 2.4. "Type 1B dual-fuel engine"  
means a dual-fuel engine that operates over the ETC test-cycle with an average gas ratio that is not lower than 90 per cent ( $GER_{ETC} \geq 90 \%$ ), and that does not idle using exclusively diesel fuel in dual-fuel mode, and that has a diesel mode.
- 2.5. " Type 2B dual-fuel engine"<sup>1</sup>  
means a dual-fuel engine that operates over the ETC test-cycle with an average gas ratio between 10 per cent and 90 per cent ( $10 \% < GER_{ETC} < 90 \%$ ) and that has a diesel mode, or a dual-fuel engine that operates over the ETC test-cycle with an average gas ratio that is not lower than 90 per cent ( $GER_{ETC} \geq 90 \%$ ), but that can idle using exclusively diesel fuel in dual-fuel mode, and that has a diesel mode.
- 2.6. " Type 3B dual-fuel engine "<sup>2</sup>  
means a dual-fuel engine that operates over the ETC test-cycle with an average gas ratio that does not exceed 10 per cent ( $GER_{ETC} \leq 10 \%$ ) and that has a diesel mode.

### 3 DUAL-FUEL SPECIFIC ADDITIONAL APPROVAL REQUIREMENTS

#### 3.1. Dual-fuel engine family

##### 3.1.1. Criteria for belonging to a dual-fuel engine family

All engines within a dual-fuel engine family shall belong to the same type of dual-fuel engines defined in section 2 and operate with the same types of fuel or when appropriate with fuels declared according to this Regulation as being of the same range(s).

All engines within a dual-fuel engine family shall meet the criteria defined by this Regulation for belonging to a compression ignition engine family.

The difference between the highest and the lowest  $GER_{ETC}$  ( i.e. the highest  $GER_{ETC}$  minus the lowest  $GER_{ETC}$ ) within a dual-fuel engine family shall not exceed 30 per cent.

##### 3.1.2. Selection of the parent engine

The parent engine of a dual-fuel engine family shall be selected according to the criteria defined by this Regulation for selecting the parent engine of a compression ignition engine family.

##### 3.1.3. Extension to include a new engine system into an dual-fuel engine-family

At the request of the manufacturer and upon approval of the Approval Authority, a new dual-fuel engine may be included as a member of a certified dual-fuel engine family if the criteria specified in sections 3.2.2.1. are met.

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<sup>1</sup> Type 2A dual-fuel engines and vehicles are neither defined nor allowed by this Regulation

<sup>2</sup> Type 3A dual-fuel engines and vehicles are neither defined nor allowed by this Regulation

If the elements of design of the parent engine system are representative of those of the new engine system, then the parent engine system shall remain unchanged and the manufacturer shall modify the documentation package according to paragraph 12. of this annex.

If the new engine system contains elements of design that are not represented by the parent engine system but itself would represent the whole family, then the new engine system shall become the new dual-fuel-parent engine. In this case the new elements of design shall be demonstrated to comply with the provisions of this regulation, and the documentation package shall be modified according to paragraph 12. of this annex.

#### 3.1.4. Extension to address a design change that affects the dual-fuel engine system

At the request of the manufacturer and upon approval of the Approval Authority, an extension of an existing certificate may be granted in the case of a design change of the dual-fuel engine system if the manufacturer demonstrates that the design changes comply with the provisions of this annex.

The documentation package shall be modified according to paragraph 12. of this annex.

## 4 GENERAL REQUIREMENTS

### 4.1 Operating modes of dual-fuel engines and vehicles

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

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

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

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

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

4.1.2.3. Types 2B and 3B dual-fuel engines may idle using diesel fuel exclusively.

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

4.1.3.1. A Type 1B, Type 2B, or Type3B dual-fuel engine may warm-up or start using diesel fuel solely. However, in that case, it shall operate in diesel mode.

4.1.3.2. A Type 1A dual-fuel engine may warm-up or start using diesel 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 or, in absence of service mode, the vehicle shall remain stationary.

## 4.2 Operability Restriction

For the purpose of this Annex, a dual-fuel vehicle shall be designed so as to permit, at the choice of the manufacturer, one of the following operability restrictions:

- The activation of the service mode
- The inability for the engine to move the vehicle

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

When a dual-fuel engine operates in a service mode, the speed of the dual-fuel vehicle equipped with that engine shall be automatically limited to 20 km/h. This speed limitation shall be automatically deactivated when the vehicle no longer operates in service mode

When operating in service mode a dual-fuel engine is temporarily exempted from complying with the requirements related to exhaust emissions, OBD, and NO<sub>x</sub> control monitoring described in this Regulation.

### 4.2.2. Requirements regarding operability restriction

#### 4.2.2.1. Operability restriction and requirements to ensure the correct operation of NO<sub>x</sub> control measures

An operability restriction as set out in paragraph 4.2 shall not be deactivated by either the activation or deactivation of the warning and torque reduction systems specified in Section 5.5.5 of this Regulation,

The activation and the deactivation of an operability restriction as set out in paragraph 4.2 shall not activate or deactivate the warning and torque reduction systems specified in Section 5.5.5 of this Regulation

#### 4.2.2.2. Activation of an operability restriction

In the case where an operability restriction is required according to paragraph 4.2.3. “Unavailability of gaseous fuel when operating in a dual-fuel mode” because of a malfunction of the gas supply system or because of an abnormality of gas consumption, the operability restriction shall become active after the next time the vehicle is stationary or within 30 minutes after the operability restriction is required, whichever comes first.

In the case where where the operability restriction is required because of an empty gas tank, the operability restriction shall become active as soon as it is required.

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

Upon detection of an empty gaseous fuel tank, or of a malfunctioning gas supply system according to paragraph 7.3.2., or of an abnormality of gas consumption in dual-fuel mode according to paragraph 7.3.3.:

- (a) Dual-fuel engines of Type 1A shall activate one of the operability restrictions considered in this Section;
- (b) Dual-fuel engines of Types 1B, 2B and 3B shall operate in diesel mode.

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

In the case of an empty gaseous fuel tank, an operability restriction or, as appropriate according to paragraph 4.2.3., the diesel mode shall be activated according to paragraph 4.2.2.2. 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 paragraph 4.3.2., the operability restriction 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 according to paragraph 7.3.2., an operability restriction or, as appropriate according to paragraph 4.2.3., the diesel mode shall be activated according to paragraph 4.2.2.2. when the OBD system has determined the presence of a malfunction in the gas supply.

As soon as the diagnostic system concludes that the malfunction is no longer present or when the OBD information is erased by a scan tool, the operability restriction may be deactivated or, when appropriate, the dual-fuel mode may be reactivated.

- 4.2.3.2.1. If the counter specified in paragraph 4.4 that is associated with a malfunctioning gas supply system of a Type 1A dual-fuel engine is not at zero, and is consequently indicating that the monitor has detected a situation when the malfunction may have occurred for a second or subsequent time, the operability restriction shall be activated according to paragraph 4.2.2.2. when the OBD system has determined the presence of a pending malfunction of the gas supply

##### 4.2.3.2. Unavailability of gaseous fuel – abnormality of gas consumption

In case of an abnormality of gas consumption in dual-fuel mode according to paragraph 7.3.3., an operability restriction or, as appropriate according to paragraph 4.2.3., the diesel mode shall be activated according to paragraph 4.2.2.2. when the OBD system has determined the presence of a pending abnormality of the gas consumption.

As soon as the diagnostic system concludes that the malfunction is no longer present or when the OBD information is erased by a scan tool, the operability restriction 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

Dual-fuel engines and vehicles shall have a visual indicator indicating to the driver the mode under which the engine operates (dual-fuel mode, diesel mode, or, when applicable, service mode).

The characteristics and the location of this indicator are left to the decision of the manufacturer 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 OBD, correct operation of NO<sub>x</sub> control measures, 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 purposes of OBD (that is, the MI – malfunction indicator), for the purpose of ensuring the correct operation of NO<sub>x</sub> control measures, or for other engine maintenance purposes.

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

4.3.1.1. The driver shall be alerted as soon as an operability restriction requires the service mode to be activated (i.e. before it becomes actually active) Setting the dual-fuel operating mode indicator to service mode for that purpose is permitted. The service mode indication shall in any case remain displayed 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 diesel mode as soon as the engine operates on dual-fuel or on diesel mode. This indication is required at key-on during at least 1 minute. The indication shall also be given upon driver's request.

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

A dual-fuel vehicle shall be equipped with a dual-fuel warning system that alerts the driver 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 driver is permitted

The visual element of the dual-fuel warning system shall not be the same as the one used for the OBD system (that is, the MI – malfunction indicator), for the purpose of ensuring the correct operation of NO<sub>x</sub> control measures, 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 messages referred to in this paragraph may be the same as the one used for displaying additional OBD messages, messages related to correct operation of NO<sub>x</sub> control measures, or messages for other maintenance purposes.

A facility to permit the driver to dim the visual alarms provided by the warning system may be provided on vehicles for use by the rescue services or on vehicles designed and constructed for use by the armed services, civil defense, fire services and forces responsible for maintaining public order

#### 4.4. Malfunctioning gas supply counter

Type 1A dual-fuel engines shall contain a counting system to record the number of hours during which the engine has been operated while the system has detected a malfunctioning gas supply system according to paragraph 7.2.

##### 4.4.1. The activation and deactivation criteria and mechanisms of the counter dedicated to abnormality of the gaseous fuel consumption shall comply with the specifications of Appendix 2.

#### 4.5. Demonstration of the dual-fuel indicators and operability restriction

As part of the application for type-approval under this Regulation, the manufacturer shall demonstrate the operation of dual-fuel indicators and of the operability restriction in accordance with the provisions of Appendix 3

#### 4.6 [reserved]

#### 4.7 Requirements to limit Off-Cycle Emissions (OCE) and in-use emissions

##### 4.7.1 GER test at certification

An ESC test-cycle shall be performed immediately after or before having performed the ETC test-cycle where the type of dual-fuel engine has been confirmed.

The fuels used in both tests shall be the same as well as all other test conditions,

including the test bench.

The average gas ratio over this ESC test-cycle ( $GER_{ESC}$ ) is calculated using the weighted average of the consumption of both fuels over this cycle.

4.7.1.1 Type 1 dual-fuel engines  
In the case of Type 1 dual-fuel engines, the average gas ratio calculated over this ESC test-cycle ( $GER_{ESC}$ ) shall not be lower than 90 per cent ( $GER_{ESC} \geq 90 \%$ ).

4.7.1.2 Type 2 dual-fuel engines  
In the case of Type 2 dual-fuel engines, the absolute difference between the average gas ratio calculated over this ETC test-cycle ( $GER_{ETC}$ ) and the average gas ratio calculated over this ESC test-cycle ( $GER_{ESC}$ ) shall not exceed 20% of the  $GER_{ETC}$

## 5. PERFORMANCE REQUIREMENTS

5.1 Emission limits applicable to Type 1A and Type 1B dual-fuel engines operating in dual-fuel mode

5.1.1 The emission limits applicable to Type 1A and Type 1B dual-fuel engines operating in dual-fuel mode are those defined for gas engines in rows B2 (EURO V) and C (EEV) of Table 2 of paragraph 5.2.1. of this Regulation

5.1.2. The emission limits applicable to Type 1B dual-fuel engines operating in diesel-mode are those defined for diesel engines in rows B2 and C of tables 1 and 2 of paragraph 5.2.1. of this Regulation

5.2. Emission limits applicable to Type 2B dual-fuel engines operating in dual-fuel mode

5.2.1. Emission limits applicable over the ESC test-cycle

5.2.1.1. The emission limits over the ESC test-cycle applicable to Type 2B dual-fuel engines operating in dual-fuel mode are those applicable to Diesel engines over the ESC test-cycle and defined in rows B2 and C of table 1 of paragraph 5.2.1. of this Regulation

5.2.1.2. The emission limits over the ESC test-cycle applicable to Type 2B dual-fuel engines operating in diesel mode are those applicable to Diesel engines over the ESC test-cycle and defined in rows B2 and C of table 1 of paragraph 5.2.1. of this Regulation

5.2.2. Emission limits applicable over the ETC test-cycle

5.2.2.1. Emission limits for CO, NO<sub>x</sub> and PM mass

The CO, NO<sub>x</sub> and PM mass emission limits over the ETC test-cycle applicable to Type 2B dual-fuel engines operating in dual-fuel mode over the ETC test-cycle are defined in rows B2 and C of table 2 of paragraph 5.2.1. of this Regulation

5.2.2.2. Emission limits for Hydrocarbons

#### 5.2.2.2.1. NG engines

The THC, NMHC and CH<sub>4</sub> emission limits over the ETC test-cycle applicable to Type 2B dual-fuel engines operating with Natural Gas in dual-fuel mode are calculated from those applicable to Diesel and gas engines over the ETC test-cycle and defined in rows B2 and C of table 2 of paragraph 5.2.1. of this Regulation. The calculation procedure is specified in paragraph 5.2.3. of this Annex.

#### 5.2.2.2.2. LPG engines

The THC emission limits over the ETC test-cycle applicable to Type 2B dual-fuel engines operating with LPG in dual-fuel mode are those applicable to CI engines over the ETC test-cycle and defined in rows B2 and C of table 2 of paragraph 5.2.1. of this Regulation.

5.2.2.4 The emission limits over the ETC test-cycle applicable to Type 2B dual-fuel engines operating in diesel mode are those defined in rows B2 and C of table 2 of paragraph 5.2.1. of this Regulation

5.2.3. Calculation procedure to determine the hydrocarbon limits (in g/kWh) applicable to Type 2B dual-fuel engines operating in dual-fuel mode during the ETC test cycle.

The following calculation procedure applies to Type 2B dual-fuel engines tested over the ETC cycle while operating in dual-fuel mode :

- Calculate the average gas ratio  $GER_{ETC}$  over the ETC test cycle
- Calculate a corresponding  $THC_{GER}$  in g/kWh using the following formula:  
 $THC_{GER} = NMHC_{NG} + (CH_{4NG} * GER_{ETC})$
- Determine the applicable THC limit in g/kWh using the following method:  
If  $THC_{GER} \leq CH_{4NG}$ , then
  - a) THC limit value =  $THC_{GER}$  and
  - b) No applicable CH<sub>4</sub> and NMHC limit value  
If  $THC_{GER} > CH_{4NG}$ , then
  - a) No applicable THC limit value; and
  - b) Both the  $NMHC_{NG}$  and  $CH_{4NG}$  limit values are applicable.

In this procedure,

- $NMHC_{NG}$  is the NMHC emission limit over the ETC test-cycle and made applicable to NG engine in rows B2 and C of table 2 of paragraph 5.2.1 of this Regulation
- $CH_{4NG}$  is the CH<sub>4</sub> emission limit over the ETC test-cycle and applicable to NG engine in rows B2 and C of table 2 of paragraph 5.2.1 of this Regulation

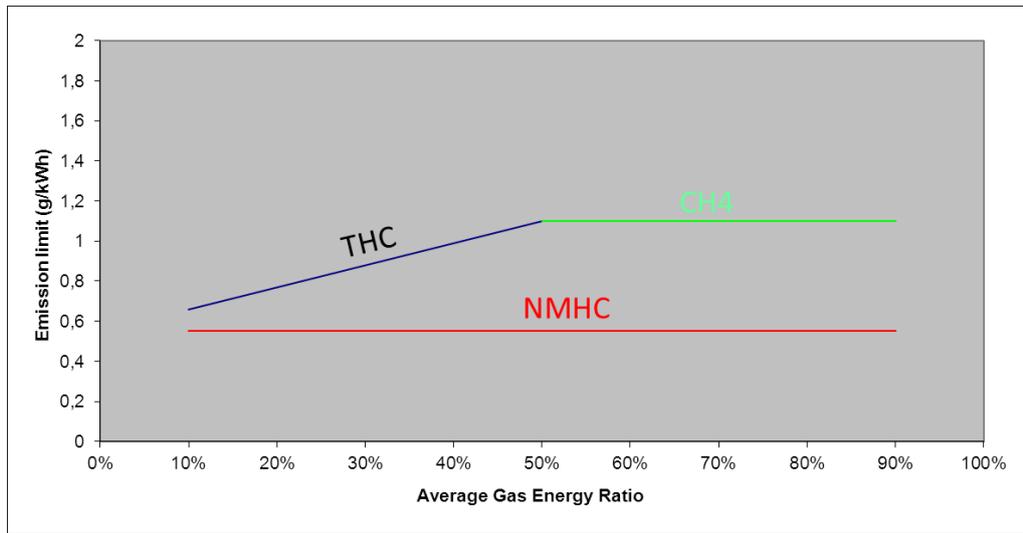


figure 1: illustration of the HC limits in the case of a Type2B dual-fuel engine operating in dual-fuel mode during the ETC cycle (natural gas dual-fuel engines)

### 5.3 Emission limits applicable to Type 3B dual-fuel engines operating in dual-fuel mode

The emissions limits applicable to Type 3B dual-fuel engines whether operating in dual-fuel mode or in diesel mode are the exhaust emission limits applicable to Diesel engines and specified in rows B2 and C of table 2 of paragraph 5.2.1. of this Regulation.

## 6 DEMONSTRATION REQUIREMENTS

### 6.1 Laboratory tests

Table 1  
Laboratory tests to be performed by a dual-fuel engine

	Type 1A	Type 1B	Type 2B	Type 3B
ETC	NMHC; CH <sub>4</sub> ; CO; NO <sub>x</sub> ; PM <sub>5</sub>	<u>Dual-fuel mode:</u> NMHC; CH <sub>4</sub> ; CO; NO <sub>x</sub> ; PM  <u>Diesel mode:</u> THC; CO; NO <sub>x</sub> ; PM	<u>Dual-fuel mode:</u> THC; NMHC; CH <sub>4</sub> ; CO; NO <sub>x</sub> ; PM  <u>Diesel mode:</u> THC; CO; NO <sub>x</sub> ; PM	THC; CO; NO <sub>x</sub> ; PM
ESC	- GER		<u>Dual-fuel mode</u> <sup>4</sup> ;	THC;

determination only <sup>3</sup> -	<u>Dual-fuel mode:</u>  - GER determination only <sup>3</sup> -  <u>Diesel mode:</u> THC; CO; NOx; PM	NMHC; CO; NOx; PM; <del>PN; NH<sub>3</sub></del>  <u>Diesel mode:</u> THC; CO; NOx; PM	CO; NOx; PM
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6.1.1. When a Type 1B, 2B or 3B dual-fuel engine is developed from an already certified diesel engine, then the engine shall be tested and approved in both dual-fuel and diesel modes

6.1.2 Dual-fuel engines are subject to the requirements of this Regulation regarding NH<sub>3</sub> emissions whether operating in diesel or dual-fuel mode.

## 6.2 Demonstrations in case of installation of a type-approved dual-fuel engine

This paragraph considers the case where the vehicle manufacturer requests approval of the installation on a vehicle of a dual-fuel engine that is type-approved to the requirements of this annex.

In this case, and in addition to the general requirements of this annex, a demonstration of the correct installation is required. This demonstration shall be done on the basis of the appropriate element of design, results of verification tests, etc. and address the conformity of the following elements to the requirements of this annex:

(a) The dual-fuel indicators and warnings as specified in this Annex (pictogram, activation schemes, etc.);

(b) The fuel storage system.

Correct indicator illumination and warning system activation will be checked. But any check shall not force dismantling the engine system (e.g. an electric disconnection may be selected).

## 6.3 Additional demonstration requirements in case of a Type2 engine

The manufacturer shall present the approval authority with evidence showing that the GER<sub>ETC</sub> span of all members of the dual-fuel engine family remains within the percentage specified in paragraph 3.1.1. (for example results of previous tests).

## 6.4 Additional demonstration requirements in case of a universal fuel range type-approval

On request of the manufacturer and with approval of the approval authority, a maximum of two times the last 10 minutes of the WHTC may be added to the adaptation run between the demonstration tests.

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<sup>3</sup> On request of the manufacturer a PEMS test may be performed instead of performing an ESC test-cycle

6.5. Requirements for demonstrating the durability of a dual-fuel engine

Provisions of Annex 7 shall apply

7 OBD REQUIREMENTS

7.1 General OBD requirements

All dual-fuel engines and vehicles, independent of whether the engine operates in dual-fuel or in diesel mode, shall comply with the OBD Stage 2 requirements specified in Annex 9A to this regulation and applicable to diesel engines.

The exemptions to these rules, including the rules concerning the OBD deficiencies and the monitoring exemptions set out in paragraph 3.3.3. of Annex 9A to this regulation shall apply.

7.2 Additional general OBD requirements in case of Type B dual-fuel engines

In the case of Type 1B, Type 2B, and Type 3B dual-fuel engines, it is allowed to have 2 separate OBD systems on-board the vehicle, one operating in dual-fuel mode, the other operating in diesel mode. It shall be possible to retrieve OBD information separately from each of these systems according to the requirements of Annex 9A to this Regulation.

7.3. Additional OBD requirements for dual-fuel mode

7.3.1. Monitoring requirements regarding the dual-fuel engine system

7.3.1.1. Monitoring requirements regarding the gas injection system

The gas injection system electronics, fuel quantity and timing actuator(s) shall be monitored for circuit continuity (i.e. open circuit or short circuit) and total functional failure when the engine operates in dual-fuel mode.

7.3.23. Monitoring of dual-fuel mode specific catalysts

In the case of a catalyst that is solely used in dual-fuel mode, the OBD system shall monitor for the complete removal and for major functional failure of that catalyst when the engine operates in dual-fuel mode

Notes:

- the replacement of the catalyst system by a bogus system (intentional major functional failure) shall be considered as a major functional failure.
- all dual-fuel specific catalyst shall be considered where fitted in a separate housing, that may or may not be part of a deNOx system or particulate filter.

7.4 Switch to Diesel mode

In the case when the OBD systems of Type 1B, Type 2B, and Type 3B dual-fuel engines concludes that a malfunction has occurred when running in dual-fuel mode, it is permitted to automatically switch to diesel mode

- 7.4.1. When the OBD systems of Type 1B, Type 2B, and Type 3B dual-fuel engines determines that a malfunction of the gas injection system or of a catalyst specific to dual-fuel mode has occurred when running in dual-fuel mode, it is permitted to automatically switch to diesel mode and to switch off the malfunction indicator. In that case, however, the status of the Diagnostic Trouble Code (DTC) associated to the concerned malfunction and of the associated counters shall be kept frozen until the next time the engine switches back to the dual-fuel mode.

## 8. REQUIREMENTS TO ENSURE THE CORRECT OPERATION OF NO<sub>x</sub> CONTROL MEASURES

- 8.1. Section 5.5 (on correct operation of NO<sub>x</sub> control measures) to this Regulation shall apply to dual-fuel engines and vehicles, whether operating in dual-fuel mode or, in the case of Types 1B, 2B, and 3B dual-fuel engines, in diesel mode.

- 8.2. When a service mode is available it is allowed to switch to that mode instead of applying the torque reduction considered in section 5.5. The engine shall then stay in service mode until the issue causing the torque reduction is fixed

- 8.3. Dual-fuel engines of Types 1B, 2B, and 3B

- 8.3.1 In the case of Type 1B, Type 2B, and Type 3B dual-fuel engines, the torque reduction defined in section 5.5.5.3 shall be calculated on the basis of the lowest of the maximum torques obtained in diesel mode and in dual-fuel mode.

- 8.3.2 In the case of Type 1B, Type 2B, and Type 3B dual-fuel engines operating in dual-fuel mode, if a torque reduction is required according to Section 5.5, the system may either

- apply the torque reduction required in section 8.3.1, or
- automatically switch to diesel mode or service mode and stay in that mode until the issue causing inducement is fixed,

- 8.3.3 Switching to diesel mode or service mode and staying in that mode until the issue causing inducement is fixed is mandatory in the case when, in dual-fuel mode, it is not possible to reduce the torque to the level required in section 8.3.1.

## 9 CONFORMITY OF IN-SERVICE ENGINES OR VEHICLES/ENGINES

The conformity of in-service dual-fuel engines and vehicles shall be performed according to the requirements specified in Annex 8, with the exceptions set out in paragraphs 9.1 to 9.3

- 9.1. The emission tests shall be performed in dual-fuel mode and, in case of Type 1B, 2B, and 3B also in diesel mode.

- 9.2. The emission limits considered when evaluating the conformity are those set out in section 5 (“Performance requirements”) of this Annex.

- 9.3. Additional requirements for Type 1B, Type 2B and Type 3B dual-fuel engines

- 9.3.1. The emission test in diesel mode shall be performed on the same engine

immediately after, or before, the emission test is performed in dual-fuel mode.

- 9.3.2. Paragraph 5.3 of Annex 8 shall not apply. The confirmatory test may instead be regarded as non-satisfactory when, from tests of two or more engines representing the same engine family, for any regulated pollutant component, the limit value as specified in this Annex is exceeded significantly either in dual-fuel mode or in diesel mode.

## 10 ADDITIONAL TEST PROCEDURES

### 10.1. Additional emission test procedure requirements for dual-fuel engines

- 10.1.1. Dual-fuel engines shall comply with the requirements of Appendix 4 in addition to the requirements of this Regulation (including Annex 4) when performing an emission test.

## 11. DOCUMENTATION REQUIREMENTS

### 11.1. Documentation for installing in a vehicle a type approved dual-fuel engine

The manufacturer of a dual-fuel engine type-approved as separate technical unit shall include in the installation documents of its engine system the appropriate requirements that will ensure that the vehicle, when used on the road or elsewhere as appropriate, will comply with the requirements of this annex. This documentation shall include but is not limited to:

- (a) The detailed technical requirements, including the provisions ensuring the compatibility with the OBD system of the engine system;
- (b) The verification procedure to be completed.

The existence and the adequacy of such installation requirements may be checked during the approval process of the engine system.

- 11.1.1. In the case when the vehicle manufacturer who applies for approval of the installation of the engine system on the vehicle is the same manufacturer who received the type-approval of the dual-fuel engine as a separate technical unit, the documentation specified in paragraph 11.1. is not required.

## 12. APPENDICES

Appendix 1 Types of dual-fuel engines and vehicles - illustration of the definitions and requirements

Appendix 2 to [4] [to be documented]

## Annex 11 - Appendix 1

### Types of dual-fuel engines and vehicles - illustration of the definitions and requirements

	$GER_{ETC}^5$	idle on diesel	warm-up on diesel	operation on diesel solely	service-mode	comments
Type 1A	$GER_{ETC} \geq 90\%$	NOT Allowed	Allowed	NOT Allowed	Allowed	
Type 1B	$GER_{ETC} \geq 90\%$	Allowed only on Diesel mode	Allowed only on Diesel mode	Allowed only on Diesel mode	Allowed <sup>6</sup>	
Type 2A	<b>NEITHER DEFINED NOR ALLOWED</b>					
Type 2B	$10\% < GER_{ETC} < 90\%$	Allowed	Allowed only on Diesel mode	Allowed only on Diesel mode	Allowed <sup>6</sup>	$GER_{ETC} \geq 90\%$ allowed <sup>7</sup>
Type 3A	<b>NEITHER DEFINED NOR ALLOWED</b>					
Type 3B	$GER_{ETC} \leq 10\%$	Allowed	Allowed only on Diesel mode	Allowed only on Diesel mode	Allowed <sup>6</sup>	

<sup>5</sup> This average Gas Energy Ratio  $GER_{ETC}$  is calculated over the ETC test-cycle

<sup>6</sup> Automatic switch-over to diesel mode allowed

<sup>7</sup> idling exclusively on diesel fuel in dual-fuel mode

## **Appendices 2 to [4]**

[to be documented]