This document (GFV-19-2) is a working document describing the complementary specifications to R49 (rev6 – 6th series of amendments) in order to enable the type approval of new **EURO VI - heavy duty dual-fuel engines and vehicles (EURO VI - HDDF)**.

It has been prepared by the GFV informal HDDF Task Force and finally reviewed in the 19th GFV meeting on 08 March 2012.

The text is approved in the 19th GFV informal GRPE group meeting on the 8th of March 2012. It needs only some editorial improvements. This document will, after these editorial improvements, be send to the GRPE secretariat to be addressed as a formal document for the 64th GRPE session.

The appendixes 3, 4, 5 and 6 are not yet finalized and will further be discussed in the HDDF- TF and GFV. When these appendixes are
finalized and approved in the GFV these will be submitted as an informal document to the GRPE in due time for the 64th GRPE session.

Regulation R49 (Revision 6 – 6th series of amendments)

Modifications to section 2 (“Definitions”)

Section 2 is amended to include:

"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.

"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.

"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.

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

"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.[1]

[1] for example in case of an empty gas tank

Regulation R49 (Revision 6 – 6th series of amendments)

Modifications to section 4 ("Approval")

Paragraph 4.3 is amended to read:

4.3. **In order to receive a type-approval of a dual-fuel engine or engine family as a separate technical unit, type-approval of a dual-fuel vehicle with an approved dual-fuel engine with regard to emissions, or a type-approval of a dual-fuel vehicle with regard to emissions, the manufacturer shall, in addition to the requirements of paragraphs 4.1 demonstrate that the dual-fuel vehicles or engine are subject to the tests and comply with the requirements set out in Annex 15**

Section 4.6 is amended to read:

4.6. Requirements on universal fuel range type-approval

4.6.1. The parent engine shall meet the requirements of this Regulation on the appropriate reference fuels specified in Annex 5. Specific requirements shall apply to **engines fuelled with natural gas / biomethane (incl. dual-fuel engines)**, as laid down in paragraph 4.6.3.

4.6.2. If the manufacturer permits to operate the engine family to run on market fuels not covered by the reference fuels included in Annex 5 or the relevant market fuel standards (for example EN 228 CEN standards in the case of unleaded petrol and EN 590 CEN standard in the case of diesel), such as running on B100, the manufacturer shall, in addition to the requirements in paragraph 4.6.1.:

(a) declare the fuels the engine family is capable to run on in paragraph 3.2.2.2.1. of Part 1 of Annex 1;

(b) demonstrate the capability of the parent engine to meet the requirements of this Regulation on the fuels declared;

(c) be liable to meet the requirements of in-service conformity specified in paragraph 9. on the fuels declared, including any blend between the declared fuels and the relevant market fuels and standards.

4.6.3. In the case of a natural gas / **biomethane** fuelled engine the manufacturer shall demonstrate the parent engines capability to adapt to any fuel composition that may occur across the market.

4.6.3.1 In the case of **compressed natural gas / biomethane (CNG)** there are generally two types of fuel, high calorific fuel (H-gas) and low calorific fuel (L-gas), but with a significant spread within both ranges; they differ significantly in their energy content expressed by the Wobbe Index and in their λ-shift factor (S_λ). Natural gases with a λ-shift factor between 0.89 and 1.08 ($0.89 \leq S_\lambda \leq 1.08$) are considered to belong to H-range, while natural gases with a λ-shift factor between 1.08 and 1.19 ($1.08 \leq S_\lambda \leq 1.19$) are considered to belong to L-range. The composition of the reference fuels reflects the extreme variations of S_λ.

The parent engine shall meet the requirements of this Regulation on the reference fuels G_R (fuel 1) and G_{25} (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 WHTC hot cycle without measurement is permitted after the change of the fuel. After the adaptation run the engine shall be cooled down in accordance with paragraph 7.6.1. of Annex 4.

4.6.3.1.1. At the manufacturer's request the engine may be tested on a third fuel (fuel 3) if the λ-shift factor (S_λ) lies between 0.89 (that is the lower range of G_R) and 1.19 (that is the upper range of G_{25}), for example when fuel 3 is a market fuel.
The results of this test may be used as a basis for the evaluation of the conformity of the production.

4.6.3.2 In the case of liquefied natural gas / liquefied biomethane (LNG) the parent engine 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 WHTC hot cycle without measurement is permitted after the change of the fuel. After the adaptation run the engine shall be cooled down in accordance with paragraph 7.6.1. of Annex 4.

4.6.4. In the case of an engine fuelled with **compressed natural gas / biomethane (CNG)** 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. The fuels are G_R (fuel 1) and G_{23} (fuel 3) for the H-range of gases and G_{25} (fuel 2) and G_{23} (fuel 3) for the L-range of gases. The parent engine shall meet the requirements of this Regulation at both positions of the switch without any readjustment to the fuelling between the two tests at each position of the switch. One adaptation run over one WHTC hot cycle without measurement is permitted after the change of the fuel. After the adaptation run the engine shall be cooled down in accordance with paragraph 7.6.1. of Annex 4.

Section 4.7 is amended to read:

4.7. Requirements on restricted fuel range type-approval in case of positive ignition engines fuelled with **compressed natural gas / biomethane** (CNG) or LPG.

Paragraph 4.9 is amended and renumbered to read:

4.5.1. Tables summarising the requirements for approval of NG-Fuelled engines, LPG-Fuelled engines **and dual-fuelled engines** are provided in Appendix 4.

Section 4.8 is renumbered, to read:

4.9. Exhaust emissions type-approval of a member of a family

A new section 4.8 is introduced, to read:

4.8. Requirements on fuel specific type-approval in the case of engines fuelled with liquefied natural gas / liquefied biomethane (LNG)

In case of liquefied natural gas / liquefied biomethane, a fuel specific type-approval may be granted subject to the requirements specified in ~~points~~ sections 4.8.1. to 4.8.2.

4.8.1. Conditions for applying for a fuel specific type approval in the case of engines fuelled with liquefied natural gas / liquefied biomethane (LNG).

4.8.1.1. The manufacturer can only apply for a fuel specific type-approval in the case of the engine being calibrated for a specific LNG gas composition[2] resulting in a λ-shift factor not differing by more than 3% from the λ-shift factor of the G_{20} fuel specified in Annex 5~~,~~ and the ethane content of which does not exceed 1.5%

4.8.1.2. In all other cases the manufacturer shall apply for a universal fuel type approval according to the specifications of paragraph 4.6.3.2.

4.8.2 Specific test requirements in the case of a fuel specific type approval (LNG)

4.8.2.1 In the case of a dual-fuel engine family where the engines are calibrated for a specific LNG gas composition[2] resulting in a λ-shift factor not differing by more than 3% from the λ-shift factor of the G_{20} fuel specified in Annex 5, and the ethane content of which does not exceed 1.5%, the parent engine shall only be tested on the G_{20} reference gas fuel, as specified in Annex 5.

Paragraph 4.12.3.3.6 is completed, to read:

4.12.3.3.6. For natural gas / biomethane fuelled engines the approval mark shall contain a letter/s after the national symbol. In order to distinguish for which range of gases the approval has been granted, this letter/s will be as follows:

(a) H in case of the engine being approved and calibrated for the H-range of gases;
(b) L in case of the engine being approved and calibrated for the L-range of gases;
(c) HL in case of the engine being approved and calibrated for both the H-range and L-range of gases ;
(d) Ht in case of the engine being approved and calibrated for a specific gas composition in the H-range of gases and transformable to another specific gas in the H-range of gases by fine tuning of the engine fuelling;
(e) Lt in case of the engine being approved and calibrated for a specific gas composition in the L-range of gases and transformable to another specific gas in the L-range of gases after fine tuning of the engine fuelling;

[2] This would typically be the case of a liquefied bio-methane

(f) HLt in the case of the engine being approved and calibrated for a specific gas composition in either the H-range or the L-range of gases and transformable to another specific gas in either the H-range or the L-range of gases by fine tuning of the engine fuelling.

(g) LNG_{20} in case of the engine being approved and calibrated for a specific liquefied natural gas / liquefied biomethane composition resulting in a λ-shift factor not differing by more than 3% the λ-shift factor of the G_{20} gas specified in Annex 5, and the ethane content of which does not exceed 1.5%

(h) LNG in case of the engine being approved and calibrated for any other liquefied natural gas / liquefied biomethane composition

A new paragraph 4.12.3.3.7 is introduced to read:

4.12.3.3.7. 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.

This series of digits will be constituted of two digits for the dual-fuel type followed by the letter(s) specified in paragraphs 4.12.3.3.1 to 4.12.3.3.6. as appropriate.

The two digits identifying the dual-fuel engines types according to the definitions of Annex 15 are the following:

- 1A for dual-fuel engines of Type 1A;
- 1B for dual-fuel engines of Type 1B;
- 2A for dual-fuel engines of Type 2A;
- 2B for dual-fuel engines of Type 2B;
- 3B for dual-fuel engines of Type 3B;

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Modifications to section 6 (“Installation on the vehicle”)

In section 6.2 (“Installation of a type-approved engine on a vehicle”) a new section 6.2.1 is introduced, to read:

6.2.1 The installation of a dual-fuel engine type-approved as a separate technical unit on a vehicle shall, in addition, meet the requirements of paragraph 6.3 of Annex 15 and according to section 8.2 of Annex 15, meet the manufacturer's installation requirements as specified in Part 1 of Annex 1;

Regulation R49 (Revision 6 – 6th series of amendments)

Modifications to section 7 ("Engine Family")

Paragraph 7.1. is completed, to read:

7.1. Parameters defining the engine family

The engine family, as determined by the engine manufacturer shall comply with paragraph 5.2. of Annex 4.
In case of a dual-fuel engine, the engine family shall also comply with the additional requirements of paragraph 3.1.1. of Annex 15.

Paragraph 7.2. is completed, to read :

7.2 Choice of the parent engine

The parent engine of the family shall be selected in accordance with the requirements set out in paragraph 5.2.4. of Annex 4.
In case of a dual-fuel engine, the parent engine family shall also comply with the additional requirements of paragraph 3.1.2. of Annex 15.

Paragraph 7.3 is renumbered, to read:

7.4. Parameters for defining an OBD-engine family

A new section 7.3 is introduced, to read:

7.3. Extension to include a new engine system into an engine-family

7.3.1. At the request of the manufacturer and upon approval of the Approval Authority, a new engine system may be included as a member of a certified engine family if the criteria specified in paragraph 7.1. are met.

7.3.2. If the elements of design of the parent engine system are representative of those of the new engine system according to paragraph 7.2. or, in the case of dual-fuel engines, to paragraph 3.1.2. of Annex 15 , then the parent engine system shall remain unchanged and the manufacturer shall modify the information document specified in Annex 1.

7.3.3. If the new engine system contains elements of design that are not represented by the parent engine system according to paragraph 7.2. or, in the case of dual-fuel engines, to paragraph 3.1.2. of Annex 15, but itself would represent the whole family according to these paragraphs, then the new engine system shall become the new parent engine. In this case the new elements of design shall be

demonstrated to comply with the provisions of this Regulation and the information document specified in Annex 1 shall be modified.

Regulation R49 (Revision 6 – 6th series of amendments)

Modifications to Appendix 4 ("Summary of approval process")

Title is amended, to read:

> Summary of approval process **for dual-fuel engines fuelled with natural gas / biomethane or LPG**

A new table is introduced, to read:

Dual-fuel type [3]	Diesel mode	Dual-fuel mode			
		CNG	LNG	LNG_{20}	LPG
1A		Universal or restricted (2 tests)	Universal (2 tests)	Fuel specific (1 test)	Universal or restricted (2 tests)
1B	Universal (1 test)	Universal or restricted (2 tests)	Universal (2 tests)	Fuel specific (1 test)	Universal or restricted (2 tests)
2A		Universal or restricted (2 tests)	Universal (2 tests)	Fuel specific (1 test)	Universal or restricted (2 tests)
2B	Universal (1 test)	Universal or restricted (2 tests)	Universal (2 tests)	Fuel specific (1 test)	Universal or restricted (2 tests)
3B	Universal (1 test)	Universal or restricted (2 tests)	Universal (2 tests)	Fuel specific (1 test)	Universal or restricted (2 tests)

[3] According to the definitions of Annex 15

Modifications to Appendix 1 to Annex 1

New explanatory notes to Annexes1, 2A, 2B, and 2C are introduced, to read:

(d) When required by this Regulation

(df) In case of a dual-fuel engine or vehicle (types as defined in Annex 15)

(dg) Except for dual-fuel engines or vehicles (types as defined in Annex 15)

(dh) In case of a dual-fuel engine or vehicle, the type of gaseous fuel used in dual-fuel mode shall not be struck out

(di) In the case of Type 1B, Type 2B, and Type 3B of dual-fuel engines (types as defined in Annex 15)

Modifications to Part 1 of Annex 1

Row 3.2.1.1. is amended, to read:

3.2.1.1. Working principle: positive ignition/compression ignition/**dual-fuel** (1)
Cycle four stroke / two stroke/ rotary (1)

A new row 3.2.1.1.1. is introduced, to read:

3.2.1.1.1. Type of dual-fuel engine: Type 1A/Type 1B/Type 2A/Type 2B/Type 3B (1) (df)
Gas Energy Ratio over the hot part of the WHTC test-cycle (df):……%

A new row 3.2.1.6.2. is introduced, to read:

3.2.1.6.2. Idle on Diesel: yes/no (1) (df)

Row 3.2.2.2. is amended, to read:

3.2.2.2. Heavy duty vehicles Diesel/Petrol/LPG/NG-H/NG-L/NG-HL/Ethanol (ED95)/ Ethanol (E85)/**dual-fuel** (1) **(dh)**

Row 3.2.4.2. is amended, to read:

3.2.4.2. By fuel injection (**only** compression ignition **or dual-fuel**): yes/no (1)

A new row 3.2.12.7.0.6. is introduced, to read:

3.2.12.7.0.6. When appropriate, manufacturer reference of the documentation for installing the dual-fuel engine in a vehicle

Row 3.2.17. is amended, to read:

3.2.17. Specific information related to gas fuelled engines **and dual-fuel engines** for heavy-duty vehicles (in the case of systems laid out in a different manner, supply equivalent information)

Row 3.5.4.1. is amended, to read:

3.5.4.1. CO2 mass emissions WHSC test (dg):…… g/kWh

A new row 3.5.4.1.1. is introduced, to read:

3.5.4.1.1. For dual-fuel engines, CO2 mass emissions WHSC test in diesel mode (d) :…… g/kWh
For dual-fuel engines, CO2 mass emissions WHSC test in dual-fuel mode (d) (if applicable) :…… g/kWh

Row 3.5.4.2. is amended, to read:

3.5.4.2. CO2 mass emissions WHTC test (dg):…… g/kWh

A new row 3.5.4.2.1. is introduced, to read:

3.5.4.2.1. For dual-fuel engines, CO2 mass emissions WHTC test in diesel mode (d) :…… g/kWh
For dual-fuel engines, CO2 mass emissions WHTC test in dual-fuel mode (d) :…… g/kWh

Row 3.5.5.1. is amended, to read:

3.5.5.1. Fuel consumption WHSC test [(dg)]:…… g/kWh

A new row 3.5.5.1.1. is introduced, to read:

3.5.5.1.1. For dual-fuel engines, Fuel consumption WHSC test in diesel mode [(d)] :…… g/kWh
For dual-fuel engines, Fuel consumption WHSC test in dual-fuel mode [(d)] :…… g/kWh

Row 3.5.5.2. is amended, to read:

3.5.5.2. Fuel consumption WHTC test [(dg)]:…… g/kWh

A new row 3.5.5.2.1. is introduced, to read:

3.5.5.2.1. For dual-fuel engines, Fuel consumption WHTC test in diesel mode [(d)] :…… g/kWh
For dual-fuel engines, Fuel consumption WHTC test in dual-fuel mode [(d)] :…… g/kWh

Modifications to the Appendix to information document in Annex 1

Paragraph 5.1. is amended, to read:

5.1. Engine test speeds for emissions test according to annex **4** [(9)] **or Engine test speeds for emissions test in dual-fuel mode according to annex 4** [(9)(df)]

A new section 5.1.1. is introduced, to read:

5.1.1. Engine test speeds for emissions test in diesel mode according to annex 4 [(9)(df)(di)]

Low speed (nlo) ……..rpm
High speed (nhi) ……..rpm
Idle speed ……..rpm
Preferred speed……..rpm
n95h……..rpm

Paragraph 5.2. is amended, to read:

5.2. Declared values for power test according to Regulation 85 **or Declared values for power test in dual-fuel mode according to Regulation 85** [(df)]

A new section 5.2.6. is introduced, to read:

5.2.6. Declared values for power test in diesel mode according to Regulation 85 [(df)(di)]
5.2.6.1. Idle speed ……..rpm
5.2.6.2. Speed at maximum power ……..rpm
5.2.6.3. Maximum power ……..kW
5.2.6.4. Speed at maximum torque……..rpm
5.2.6.5. Maximum torque……..Nm

Modifications to the Addenda in Annexes 2A and 2C

Paragraph 1.1.5. is completed, to read:

1.1.5 Category of engine: Diesel/Petrol/LPG/NG-H/NG-L/NG-HL/Ethanol (ED95)/ Ethanol (E85)/**dual-fuel** [(1)] **[(dh)]**

New paragraph 1.1.5.1 is introduced, to read:

1.1.5.1. Type of dual-fuel engine: Type 1A/Type 1B/Type 2A/Type 2B/Type 3B [(1)] [(df)]

Paragraph 1.4. is amended, to read:

1.4. Emission levels of the engine/parent engine [(1)]:
Deterioration Factor (DF): calculated/fixed[(1)]
Specify the DF values and the emissions on the WHSC (if applicable) and WHTC tests in the table below
In case of engines ~~If CNG and LPG fuelled engines are~~ tested on different reference fuels **(whether NG or LPG)**, the tables shall be reproduced for each reference fuel tested.
In case of Type 1B and Type 2B dual-fuel engines, the tables shall be reproduced for each mode tested (dual-fuel and diesel modes)

Table 4 is amended, to read:

WHSC test (if applicable)							
DF Mult/add[(1)]	CO	THC[(d)]	**NMHC[(d)]**	NOX	PM Mass	NH3	PM Number
Emissions	CO (mg/kWh)	THC[(d)] (mg/kWh)	**NMHC[(d)] (mg/kWh)**	NOX (mg/kWh)	PM Mass (mg/kWh)	NH3 ppm	PM Number (#/kWh)
Test result							
Calculated with DF							
CO_2 emissions mass emission[(d)]: ……..……..……g/kWh Fuel consumption[(d)]: ……..g/kWh							

Table 5 is amended, to read:

WHTC test								
DF Mult/add[(1)]	CO	THC[(d)]	**NMHC[(d)]**	**CH_4[(d)]**	NOx	PM Mass	NH3	PM Number
Emissions	CO mg/kWh	THC[(d)] (mg/kWh)	**NMHC[(d)] mg/kWh**	**CH_4[(d)] (mg/kWh)**	NOx (mg/kWh)	PM Mass (mg/kWh)	NH3 ppm	PM Number (#/kWh)
Cold start								
Hot start w/o regeneration								
Hot start with regeneration[(1)]								
$k_{r,u}$ (mult/add) [(1)] $k_{r,d}$ (mult/add) [(1)]								
Weighted test result								
Final test result with DF								

CO_2 emissions mass emission[(d)]:..……..……g/kWh Fuel consumption[(d)]: ……..g/kWh

Modifications to Annex 3

Table 2 is amended, to read:

Engine type codes for approval marks

Engine type	Code
Diesel fuelled CI engine	D
Ethanol (ED95) fuelled CI engine	ED
Ethanol (E85) fuelled PI engine	E85
Petrol fuelled PI engine	P
LPG fuelled PI engine	Q
Natural gas fuelled PI engine	See paragraph 4.12.3.3.6. of this Regulation
Dual-fuel engines	**See paragraph 4.12.3.3.7. of this Regulation**

Modifications to Annex 5 (reference fuels)

Section “data for CI engines” is amended, to read:

Technical data on fuels for testing compression-ignition **and dual-fuel** engines

Section “data for CI engines” is numbered and amended, to read:

Technical data on fuels for testing positive-ignition **and dual-fuel** engines

A new type is added to the section “data for CI and HDDF engines”, to read:

Type: NG/Biomethane

Characteristics	Units	Basis	Limits		Test method
			minimum	maximum	
Reference fuel G_{20}					
Composition:					
Methane	% mole	100	99	100	ISO 6974
Balance [1]	% mole	—	—	1	ISO 6974
N_2	% mole				ISO 6974
Sulphur content	mg/m^3 [2]	—	—	10	ISO 6326-5
Wobbe Index (net)	MJ/m^3 [3]	48,2	47,2	49,2	

[1] Inerts (different from N_2) + C_2 + C_2+.
[2] Value to be determined at 293,2 K (20 °C) and 101,3 kPa.
[3] Value to be determined at 273,2 K (0 °C) and 101,3 kPa.

Modifications to Annex 7 (Durability)

Paragraph 4.2. is amended, to read:

3.7.1. The engines shall meet the respective emission limits for each pollutant, as given in paragraph 5.3. of this Regulation, after application of the deterioration factors to the test result as measured in accordance with Annex ~~III~~ **4** (e_{gas}, e_{PM}). Depending on the type of deterioration factor (DF), the following provisions shall apply:

Modifications to Annex 9B (OBD)

Paragraph 4.2. is amended, to read:

4.2. Monitoring requirements

All emission-related components and systems included in an engine system shall be monitored by the OBD system in accordance with the requirements set in Appendix 3 **and, in the case of dual-fuel engines or vehicles in section 7 of Annex 15**. However, the OBD system is not required to use a unique monitor to detect each malfunction referred to in Appendix 3 **and, in the case of dual-fuel engines or vehicles in section 7 of Annex 15**.

The OBD system shall also monitor its own components.

The items of Appendix 3 list the systems or components required to be monitored by the OBD system and describes the types of monitoring expected for each of these components or systems (i.e. emission threshold monitoring, performance monitoring, total functional failure monitoring, or component monitoring).

The manufacturer can decide to monitor additional systems and components.

Paragraph 4.2.1. is amended, to read:

4.2.1. Selection of the monitoring technique

Approval authorities may approve a manufacturer's use of another type of monitoring technique than the one mentioned in Appendix 3 **or, in the case of dual-fuel engines or vehicles in section 7 of Annex 15**. The chosen type of monitoring shall be shown by the manufacturer, to be robust, timely and efficient (i.e. through technical considerations, test results, previous agreements, etc.).

In case a system and/or component is not covered by Appendix 3 **or, in the case of dual-fuel engines or vehicles in section 7 of Annex 15,** the manufacturer shall submit for approval to the Approval Authority an approach to monitoring. The Approval Authority will approve the chosen type of monitoring and monitoring technique (i.e. emission threshold monitoring, performance monitoring, total functional failure monitoring, or component monitoring) if it has been shown by the manufacturer, by reference to those detailed in Appendix 3 **or, in the case of dual-fuel engines or vehicles in section 7 of Annex 15**, to be robust, timely and efficient (i.e. through either technical considerations, test results, previous agreements, etc.).

Paragraph 6.3.2.1.2. is amended, to read:

6.3.2.1.2. Performance monitoring

At the request of the manufacturer and with the agreement of the Approval Authority, in the case of performance monitoring, the OTL may be exceeded by more than 20 per cent. Such request shall be justified on a case by case basis.

In the case when the performance monitoring of an abnormality of the gaseous fuel consumption of a dual-fuel engine or vehicle is required by Annex 15, a deteriorated component is qualified without reference to the OTL.

Title of Item 1 to the technical compliance report in Appendix 4 is amended, to read:

Information concerning the OB**D**~~S~~ system

Section 2 of Item 2 to the technical compliance report in Appendix 4 is amended, to read:

Monitoring
The monitors comply with the requirements of **section** 4.2. of this Annex

Annex 15

TECHNICAL REQUIREMENTS FOR DIESEL-GAS DUAL-FUEL ENGINES AND VEHICLES

1. SCOPE

This annex shall apply to dual-fuel engines and dual-fuel vehicles.

2. DEFINITIONS AND ABBREVIATIONS

2.1. "Gas Energy Ratio (GER)"
means in case of a dual-fuel engine the ratio (expressed as a percentage) of the energy content of the gaseous fuel[4] over the energy content of both fuels (diesel and gaseous).

2.2. "Average gas ratio"
means the average gas energy ratio calculated over a specific operating sequence.

2.3. "Heavy-Duty Dual-Fuel (HDDF) Type 1A engine"
means a dual-fuel engine
- that operates over the hot part of the WHTC test-cycle with an average gas ratio that is not lower than 90% ($GER_{WHTC} \geq 90\%$), and
- that does not idle using exclusively diesel fuel, and
- that has no diesel mode.

2.4. " Heavy-Duty Dual-Fuel (HDDF) Type 1B engine"
means a Dual-Fuel engine
- that operates over the hot part of the WHTC test-cycle with an average gas ratio that is not lower than 90% ($GER_{WHTC} \geq 90\%$), and
- that does not idle using exclusively diesel fuel in dual-fuel mode, and
- that has a diesel mode.

2.5. " Heavy-Duty Dual-Fuel (HDDF) Type 2A engine"
means a Dual-Fuel engine
- that operates over the hot part of the WHTC test-cycle with an average gas ratio between 10% and 90% ($10\% < GER_{WHTC} < 90\%$) and
- that has no diesel mode

or
- that operates over the hot part of the WHTC test-cycle with an average gas ratio that is not lower than 90% ($GER_{WHTC} \geq 90\%$), but
- that idles using exclusively diesel fuel, and
- that has no diesel mode.

2.6. "Heavy-Duty Dual-Fuel (HDDF) Type 2B engine "

[4] based on the lower heating value

means a Dual-Fuel engine

- that operates over the hot part of the WHTC test-cycle with an average gas ratio between 10% and 90% ($10\% < GER_{WHTC} < 90\%$) and
- that has a diesel mode

or

- that operates over the hot part of the WHTC test-cycle with an average gas ratio that is not lower than 90% ($GER_{WHTC} \geq 90\%$), but
- that can idle using exclusively diesel fuel in dual-fuel mode, and
- that has a diesel mode

2.7. "Heavy-Duty Dual-Fuel (HDDF) Type 3B engine "[5]

means a dual-fuel engine

- that operates over the hot part of the WHTC test-cycle with an average gas ratio that does not exceed 10% ($GER_{WHTC} \leq 10\%$) 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 [6], 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_{WHTC} (i.e. the highest GER_{WHTC} minus the lowest GER_{WHTC}) within a dual-fuel engine family shall not exceed 30%.

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.

4. GENERAL REQUIREMENTS

[5] HDDF Type 3A are neither defined nor allowed by this Regulation

[6] For example HDDF Type 1A, or HDDF Type 2B, or etc

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.

When a dual-fuel engine is developed from an already certified diesel engine, then re-certification is required in the diesel mode

4.1.2. Conditions for a HDDF engine to idle using diesel fuel exclusively

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

4.1.2.3. HDDF Types 2A, 2B, and 3B engines may idle using diesel fuel exclusively

4.1.3. Conditions for a HDDF engine to warm-up or start using diesel fuel solely

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 or Type 2A dual-fuel engine may warm-up or start using diesel fuel solely. However, in that case, the strategy shall be declared as an AES 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 and vehicles to operate in service mode
When its engine is operating in service mode, a dual-fuel vehicle is subject to an operability restriction and is temporarily exempted from complying with the requirements related to exhaust emissions, OBD, and NO_x control described in this Regulation.

4.2.2. Operability restriction in service mode
The operability restriction applicable to dual-fuel vehicles when they operate in service mode is the one activated by the "severe inducement system" specified in Annex 11.

The operability restriction shall not be deactivated by either the activation or deactivation of the warning and inducement systems specified in Annex 11.
The activation and the deactivation of the service mode shall not activate or deactivate the warning and inducement systems specified in Annex 11

Illustrations of the operability restriction requirements are given in Appendix 2.

4.2.2.1. 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 paragraph 4.2.3 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 operating time after the service mode is activated, whichever comes first.

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

4.2.2.2. Deactivation of the operability restriction
The operability restriction system shall be deactivated when the vehicle 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 vehicle to keep moving and eventually to move out of the main-stream traffic, upon detection of an empty gaseous fuel tank, or of a malfunctioning gas supply system according to paragraph 7.2., or of an abnormality of gas consumption in dual-fuel mode according to paragraph 7.3.,
- dual-fuel engines of Types 1A and 2A shall activate the service mode
- 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, the service mode or, as appropriate according to paragraph 4.2.3., the diesel 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 paragraph 0, 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 according to paragraph 7.2., the service mode or, as appropriate according to paragraph 4.2.3., the diesel mode shall

be activated when the DTC relevant to that malfunction has the confirmed and active status.
As soon as the diagnostic system concludes that the malfunction is no longer present or when the information, including DTCs relative to the failures, justifying its activation is erased by a scan tool, the service mode 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 and associated with a malfunctioning gas supply system 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 service mode or, as appropriate, the diesel mode shall be activated when the DTC has the status "potential".

4.2.3.3. 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., the service mode or, as appropriate according to paragraph 4.2.3., the diesel mode shall be activated when the DTC relevant to that malfunction has got the potential status.
As soon as the diagnostic system concludes that the malfunction is no longer present or when the information, including DTCs relative to the failures, justifying its activation is erased by a scan tool, 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

Dual-fuel engines and vehicles shall provide to the driver a visual indication of the mode under which the engine operates (dual-fuel mode, diesel mode, or 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 paragraph may be the same as the ones used for OBD, correct operation of NO_x 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_x control measures, 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 diesel mode as soon as the engine operates on dual-fuel or on diesel mode. This indication is required at key-on for 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_x 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 NOx 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

The system 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 shall comply with the specifications of Appendix 2.

4.4.2. It is not required to have a counter as specified in paragraph 4.4., when the manufacturer can demonstrate to the approval authority (e.g. by means of a strategy description, experimental elements, etc…) that the dual-fuel engine automatically switches to diesel mode in the case when the malfunction is detected.

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. Communicated torque

4.6.1. Communicated torque when a dual-fuel engine operates in dual-duel mode

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

(a) the reference torque curve retrievable according to the requirements related to data stream information specified in Annex 9B and referred to by Annex 8 shall be the one obtained according to Annex 4 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 diesel fuel exclusively.

4.6.2. Communicated torque when an dual-fuel engine operates in diesel mode

When a dual-fuel engine operates in diesel mode, the reference torque curve retrievable according to the requirements related to data stream information specified in Annex 9B and referred to by Annex 8 shall be the one obtained according to Annex 4 when the engine is tested on an engine test bench in diesel mode

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

Dual-fuel engines shall be subject to the requirements of Annex 10, whether operating in dual-fuel mode or in the case of Type1B, Type 2B, and Type 3B in diesel mode.

4.7.1. PEMS tests at certification

The PEMS demonstration test at type-approval required in Annex 10 shall be performed by testing the parent engine of a dual-fuel engine family when operating in dual-fuel mode.

4.7.1.1. In the case of Type 1B, Type2B, and Type3B dual-fuel engines, an additional PEMS test shall be performed in diesel mode on the same engine and vehicle immediately after of before the PEMS demonstration test performed in dual-fuel mode.
In that case, certification can only be granted if both the PEMS demonstration test in dual-fuel mode and the PEMS demonstration test in diesel mode have concluded to a pass.

4.7.2. Additional requirements

4.7.2.1. Adaptive strategies of a dual-fuel engine are allowed provided:

- The engine always remains in the HDDF type (that is Type 1A, Type 2B, etc…) that has been declared for type-approval, and
- In case of a Type 2 engine, the resulting difference between the highest and the lowest GER_{WHTC} within the family shall never exceed the percentage specified in paragraph 3.1.1. and
- These strategies are declared and satisfy the requirements of Annex 10

5. PERFORMANCE REQUIREMENTS

5.1. Emission limits applicable to HDDF Type 1A and Type 1B engines

5.1.1. The emission limits applicable to HDDF Type 1A engines and HDDF Type 1B engines operating in dual-fuel mode are those defined for PI engines in paragraph 5.3. of this Regulation

5.1.2. The emission limits applicable to HDDF Type 1B engines operating in diesel mode are those defined for CI engines in paragraph 5.3. of this Regulation

5.2. Emission limits applicable to HDDF Type 2A and Type 2B engines

5.2.1. Emission limits applicable over the WHSC test-cycle

5.2.1.1. For HDDF Type 2A and Type 2B engines, the exhaust emission limits (incl. the PM number limit) over the WHSC test-cycle applicable to HDDF Type 2A engines and HDDF Type 2B engines operating in dual-fuel mode are those applicable to CI engines over the WHSC test-cycle and defined in the table of paragraph 5.3. of this Regulation

5.2.1.2. The emission limits (incl. the PM number limit) over the WHSC test-cycle applicable to HDDF Type 2B engines operating in diesel mode are those defined for CI engines in paragraph 5.3. of this Regulation

5.2.2. Emission limits applicable over the WHTC test-cycle

5.2.2.1. Emission limits for CO, NO_x, NH_3, and PM mass

The CO, NO_x, NH_3, and PM mass emission limits over the WHTC test-cycle applicable to HDDF Type 2A engines and HDDF Type 2B engines operating in dual-fuel mode are those applicable to both CI and PI engines over the WHTC test-cycle and defined in paragraph 5.3. of this Regulation

5.2.2.2. Emission limits for Hydrocarbons

5.2.2.2.1. NG engines
The THC, NMHC, and CH4 emission limits over the WHTC test-cycle applicable to HDDF Type 2A engines and HDDF Type 2B engines operating with Natural Gas in dual-fuel mode are calculated from those applicable to CI and PI engines over the WHTC test-cycle and defined in paragraph 5.3. of this Regulation. The calculation procedure is specified in paragraph 5.3. of this Annex.

5.2.2.2.2. LPG engines
The THC emission limits over the WHTC test-cycle applicable to HDDF Type 2A engines and HDDF Type 2B engines operating with LPG in dual-fuel mode are those applicable to CI engines over the WHTC test-cycle and defined in paragraph 5.3. of this Regulation.

5.2.2.3. Emission limits for PM number

5.2.2.3.1. The PM number limit over the WHTC test-cycle applicable to HDDF Type 2A engines and HDDF Type 2B engines operating in dual-fuel mode are those applicable to CI engines over the WHTC test-cycle and defined in paragraph 5.3. of this Regulation. In the case a PM number limit applicable to PI engines over the WHTC test-cycle would be defined in paragraph 5.3. of this Regulation, then the requirements of paragraph 5.2.4. shall apply for calculating the limit applicable to HDDF Type 2A engines and HDDF Type 2B engines over that cycle.

5.2.2.3.2. The emission limits (incl. the PM number limit) over the WHTC test-cycle applicable to HDDF Type 2B engines operating in diesel mode are those defined for CI engines in paragraph 5.3. of this Regulation

5.2.3. Hydrocarbon limits (in mg/kWh) applicable to HDDF Type 2A engines and to HDDF Type 2B engines operating in dual-fuel mode during the WHTC test cycle.

The following calculation procedure applies for HDDF Type2A and HDDF Type 2B engines tested in the WHTC cycle while operating in dual-fuel mode :

Calculate the average gas ratio GER_{WHTC} over the hot part of the WHTC test cycle

Calculate a corresponding THC_{GER} in mg/kWh using the following formula:

$THC_{GER} = NMHC_{PI} + (CH4_{PI} * GER_{WHTC})$

Determine the applicable THC limit in mg/kWh using the following method:

If $THC_{GER} \leq CH4_{PI}$, then

a) THC limit value = THC_{GER} and

b) No applicable CH_4 and NMHC limit value

If THC_{GER} > $CH4_{PI}$, then

a) No applicable THC limit value; and

b) Both the $NMHC_{PI}$ and $CH4_{PI}$ limit values are applicable.

In this procedure,

$NMHC_{PI}$ is the NMHC emission limit over the WHTC test-cycle and made applicable to PI engine by paragraph 5.3. of this Regulation

$CH4_{PI}$ is the CH_4 emission limit over the WHTC test-cycle and applicable to PI engine by paragraph 5.3. of this Regulation

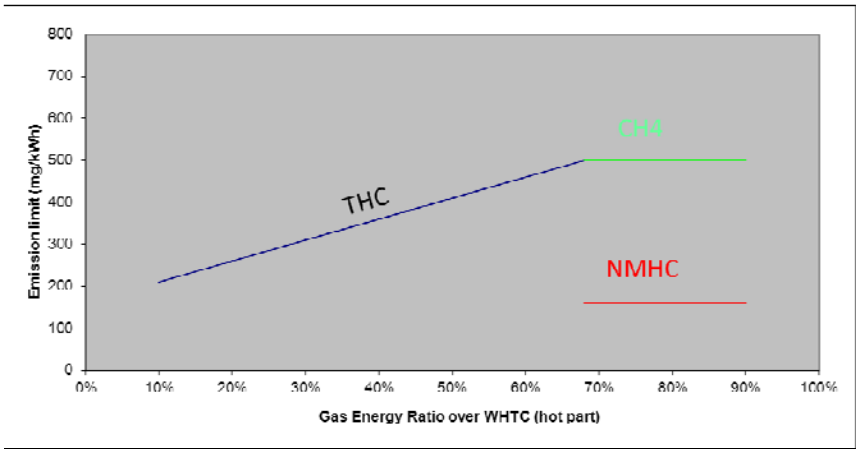

figure 1: illustration of the HC limits in the case of a HDDF Type2 engine operating in dual-fuel mode during the WHTC cycle (natural gas dual-fuel engines)

5.2.4. PM number limit (in #/kWh) applicable to HDDF Type 2A engines and to HDDF Type 2B engines operating in dual-fuel mode during the WHTC test cycle.

In the case a PM number limit applicable to PI engines over the WHTC test-cycle would be defined in paragraph 5.3. of this Regulation, the following calculation procedure shall apply to HDDF Type 1A engines, to HDDF Type 1B engines, to HDDF Type 2A engines, to HDDF Type2A and to HDDF Type 2B engines tested in the WHTC cycle while operating in dual-fuel mode :

Calculate the average gas ratio GER_{WHTC} over the hot part of the WHTC test cycle, then

Calculate the PM number limit values PN $limit_{WHTC}$ in #/kWh applicable over the WHTC test-cycle using the following formula (linear interpolation between the CI and PI PM number limit values):

PN $limit_{WHTC}$ = PN $limit_{CI/WHTC}$ + (PN $limit_{PI/WHTC}$ – PN $limit_{CI/WHTC}$)* GER_{WHTC}

where

PN $limit_{PI/WHTC}$ is the PM number limit applicable to PI engines over the WHTC test cycle

PN $limit_{CI/WHTC}$ is the PM number limit applicable to CI engines over the WHTC test cycle

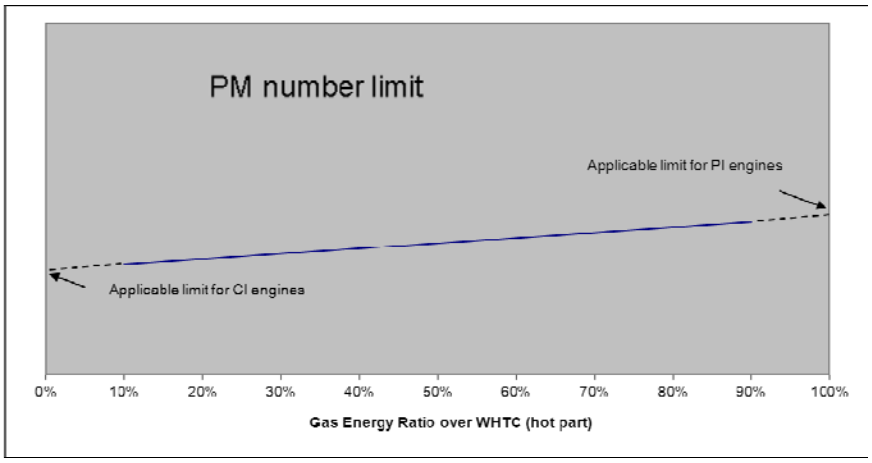

figure 2: illustration of the PN limits in the case of a HDDF Type2 engine operating in dual-fuel mode during the WHTC cycle

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

The emissions limits applicable to HDDF Type 3B engines whether operating in dual-fuel mode or in diesel mode are the exhaust emission limits applicable to CI engines.

5.4. Conformity factors

Principally, the emission limit applicable for applying the conformity factor used when performing a PEMS test, whether a PEMS test at certification or a PEMS test when checking and demonstrating the conformity of in-service engines and vehicles, shall be determined on the basis of the actual GER calculated from the fuel consumption measured over the on-road test.

However, in absence of a robust way to measure the gas or the diesel fuel consumption, the manufacturer is allowed to use the GER_{WHTC} determined on the hot part of the WHTC

6. DEMONSTRATION REQUIREMENTS

6.1. Dual-fuel engines shall be subject to the laboratory tests specified in table 1

Table 1: Laboratory tests to be performed by a HDDF engine

	Type 1A	Type 1B	Type 2A	Type 2B	Type 3B
WHTC	NMHC; CH_4;	Dual-fuel mode:	THC; NMHC; CH_4;	Dual-fuel mode:	THC;

	CO; NOx; PM; PN;NH_3	NMHC; CH_4; CO; NOx; PM; PN;NH_3 <u>Diesel mode:</u> THC; CO; NOx; PM; PN;NH_3	CO; NOx; PM; PN;NH_3	THC; NMHC; CH_4; CO; NOx; PM; PN;NH_3 <u>Diesel mode:</u> THC; CO; NOx; PM; PN;NH_3	CO; NOx; PM; PN;NH_3
WHSC	- no test -	<u>Dual-fuel mode:</u> - no test - <u>Diesel mode:</u> THC; CO; NOx; PM; PN;NH_3	NMHC; CO; NOx; PM; PN;NH_3	<u>Dual-fuel mode:</u> NMHC; CO; NOx; PM; PN;NH_3 <u>Diesel mode:</u> THC; CO; NOx; PM; PN;NH_3	THC; CO; NOx; PM; PN;NH_3
WNTE laboratory test	- no test -	<u>Dual-fuel mode:</u> - no test - <u>Diesel mode:</u> THC; CO; NOx; PM	[HC]; CO; NOx; PM	<u>Dual-fuel mode:</u> [HC]; CO; NOx; PM <u>Diesel mode:</u> THC; CO; NOx; PM	THC; CO; NOx; PM

6.2. <u>Demonstrations in case of installation of type-approved HDDF engines</u>

In addition to the requirements of this Regulation related to the installation of an engine that is type-approved as separate technical unit, a demonstration of the correct installation on a vehicle of a dual-fuel engine shall be done on the basis of appropriate elements of design, results of verification tests, etc. It shall 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.
(c) The performance of the vehicle in service mode

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

6.3. <u>Demonstration requirements in case of a Type2 engine</u>

The manufacturer shall present the approval authority with evidence showing that the GER_{WHTC} span of all members of the dual-fuel engine family remains within the percentage specified in paragraph 3.1.1. (for example, through algorithms, functional analyses, calculations, simulations, results of previous tests, etc …).

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.

6.5 Demonstration 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 shall comply with the requirements specified in Annex 9A and applicable to diesel engines, independent whether operating in dual-fuel or diesel mode.

In case a dual fuel engine system is equipped with oxygen sensor(s), the requirements applicable to gas engines in item 13 in Appendix 3 of Annex 9B shall apply.

In case a dual fuel engine system is equipped with a 3-way catalyst, the requirements applicable to gas engines in items 7, 10, and 15 in Appendix 3 of Annex 9B shall apply.

7.1.1. Additional general OBD requirements in case of Type 1B, Type 2B, and Type 3B dual-fuel engines and vehicles.

7.1.1.1. In the case of malfunctions the detection of which does not depend on the operation mode of the engine, the mechanisms specified in Annex 9B 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 diesel mode).

7.1.1.2. 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

7.1.1.3. A change of the mode of operation (dual-fuel to diesel or vice-versa) shall not stop nor reset the OBD mechanisms (counters, etc…). However, in the case of failures the detection of which depends on the actual operation mode, the counters associated with these malfunctions may, at the request of the manufacturer and upon approval of the type-approval authority:

- halt and, when applicable, hold their present value when the operation mode changes;
- restart and, when applicable, continue counting from the point at which they have been held when the operation mode changes back to the other operation mode

7.1.1.4. A possible influence of the mode of operation on the malfunction detection shall not be used to extend the time until an operability restriction becomes active.

7.1.1.5. In case of a Type 1B, Type 2B, or Type 3B dual-fuel engine, the manufacturer shall specify which malfunctions are operation mode dependent. This information shall be included in the information package required in paragraph 8.1. (a) of Annex 9B. The justification for operation mode dependency shall be included in the information package required in paragraph 8.1. (b) of Annex 9B.

7.1.1.5. The following piece of information shall be added to table 1 in Appendix 5 of Annex 9B

	Freeze frame	*Data stream*
In case of Type 1B, Type 2B, and Type 3B dual-fuel engines, operation mode of the Dual-fuel Engine (dual-fuel or diesel)	x	x

7.2. Monitoring of the gas supply system

HDDF engines and vehicles shall monitor the gas supply system within the engine system (incl. the signals coming from outside of the engine system) according to the specifications of item1 in Appendix 3 to Annex 9B – component monitoring.

7.3. Monitoring of the gaseous fuel consumption

Type 1A and Type 2A dual-fuel vehicles shall include a means of determining gas fuel consumption and providing off-board access to consumption information. Abnormality of the gaseous fuel consumption (e.g. a deviation of 50% of the normal gaseous fuel consumption) shall be monitored – performance monitoring.
The monitor for insufficient gaseous fuel consumption shall run continuously whenever in dual-fuel mode, however the maximum detection period is 48 hours of operation in dual-fuel mode.
It shall not be subject to the "IUPR" requirements

7.4 OBD Deficiencies
The deficiency rules specified in Annex 9B and applicable to diesel engines shall apply to dual-fuel engines.
A deficiency that is present both in diesel mode and in dual-fuel mode shall not be counted for each mode separately.

7.5. Erasing of failure information by means of a scan-tool

7.5.1. Erasing of information by means of a scan tool, including DTCs relative to the malfunctions considered in this Annex shall be performed in accordance with Annex 9B.

7.5.2. The erasing of failure information shall only be possible under "engine-off" conditions.

7.5.3. When failure information related to the gas supply system as specified in paragraph 7.2., including the DTC, is erased, the counter associated with this failure shall not be erased.

8. REQUIREMENTS TO ENSURE THE CORRECT OPERATION OF NO_X CONTROL MEASURES

8.1. Annex 11 (on correct operation of NOx control measures) shall apply to HDDF engines and vehicles, whether operating in dual-fuel or diesel mode.

8.2. Additional general OBD requirements in case of Type 1B, Type 2B, and Type 3B dual-fuel engines and vehicles

8.2.1. In case of HDDF Type 1B, Type 2B, and Type 3B, the torque considered to apply low level inducement defined in Annex 11 shall be the lowest of the torques obtained in diesel mode and in dual-fuel mode.

8.2.2. The requirements of section 7.1.1. concerning additional general OBD requirements in case of Type 1B, type 2B, and Type 3B dual-fuel engines and vehicles shall also apply to the diagnostic system related to the correct operation of NO_x control systems.
In particular:

8.2.2.1. A possible influence of the mode of operation on the malfunction detection shall not be used to extend the time until an operability restriction becomes active.

8.2.2.2. A change of the mode of operation (dual-fuel to diesel or vice-versa) shall not stop nor reset the mechanisms implemented to comply with the specification of Annex 11 (counters, etc…). 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 type-approval authority:

- halt and, when applicable, hold their present value when the operation mode changes;
- 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.

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.

The PEMS tests shall be performed in dual-fuel mode.

9.1. In the case of Type 1B, Type 2B, and Type 3B dual-fuel engines, an additional PEMS test shall be performed in Diesel mode on the same engine and vehicle immediately after, or before, a PEMS test is performed in dual-fuel mode.

In that case the pass or fail decision of the lot considered in the statistical procedure specified in Annex 8 shall be based on the following:

- a pass decision is reached for an individual vehicle if both the PEMS test in dual-fuel mode and the PEMS test in Diesel mode have concluded a pass.
- a fail decision is reached for an individual vehicle if either the PEMS test in dual-fuel mode or the PEMS test in Diesel mode has concluded a fail.

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 (incl. Annex 4) when performing an emission test.

10.2. Additional PEMS emission test procedure requirements for dual-fuel engines

10.2.1. When subject to a PEMS test, dual-fuel engines shall comply with the requirements of Appendix 5 in addition to the other PEMS requirements of this Regulation.

10.2.2. Torque correction

When necessary, for instance because of variation of the gas fuel composition, the manufacturer may decide to correct the ECU Torque signal. In that case the following requirements shall apply

10.2.2.1. Correction of the PEMS torque signal
The manufacturer shall submit to the approval authority a description of the relationship permitting to extrapolate the real torque from the torques obtained during emission testing with the 2 appropriate reference fuels and from the actually retrievable torque in the ECU.

10.2.2.1.1. In the case when the torques obtained with the two reference fuels may be considered of the same magnitude (that is within the 7 per cent considered in paragraph 9.4.2.5. of this Regulation), the use of the corrected ECU value is not necessary

10.2.2.2. Torque value to consider in a PEMS test
For PEMS test (work based window) the corrected torque value shall result from that interpolation

10.2.2.3. Conformity of the ECU torque-signal

The "Maximum torque" method specified in Appendix 4 to Annex 8 shall be understood as demonstrating that a point between the reference maximum torque curves obtained at a certain engine speed when testing with the 2 applicable reference fuels has been reached during vehicle testing.

The value of that point shall be estimated with the agreement of the approval authority on the basis of the actual fuel composition sampled as close as possible to the engine and the power curves obtained with each of the reference fuels during the emission certification test.

11. DOCUMENTATION REQUIREMENTS

11.1. Documentation for installing in a vehicle a type approved HDDF 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 separate technical unit, the documentation specified in paragraph 11.2. is not required.

12. APPENDICES

Appendix 1	Types of HDDF engines and vehicles - illustration of the definitions and requirements
Appendix 2	Activation and deactivation mechanisms of the counter(s), warning system, operability restriction, service mode in case of HDDF engines and vehicles- Description and illustrations
Appendix 3	HDDF dual-fuel indicator, warning system, operability restriction - Demonstration requirements
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Appendix 5	Additional PEMS emission test procedure requirements for dual-fuel engines
Appendix 6	Determination of α and u_{gas} values for dual-fuel engines

Appendix 1

Types of HDDF engines and vehicles - illustration of the definitions and main requirements

	GER_{WHTC}[7]	idle on diesel	warm-up on diesel	operation on diesel solely	Operation in absence of gas	comments
Type 1A	$GER_{WHTC} \geq 90\%$	NOT Allowed	Allowed only on service mode	Allowed only on service mode	Service mode	
Type 1B	$GER_{WHTC} \geq 90\%$	Allowed only on Diesel mode	Allowed only on Diesel mode	Allowed only on Diesel & Service modes	Diesel mode	
Type 2A	$10\% < GER_{WHTC} < 90\%$	Allowed	Allowed only on service mode	Allowed only on service mode	Service mode	$GER_{WHTC} \geq 90\%$ allowed
Type 2B	$10\% < GER_{WHTC} < 90\%$	Allowed	Allowed only on Diesel mode	Allowed only on Diesel & Service modes	Diesel mode	$GER_{WHTC} \geq 90\%$ allowed
Type 3A	NEITHER DEFINED NOR ALLOWED					
Type 3B	$GER_{WHTC} \leq 10\%$	Allowed	Allowed only on Diesel mode	Allowed only on Diesel & Service modes	Diesel mode	

[7] This average Gas Energy Ratio GER_{WHTC} is calculated over the hot part of the WHTC test-cycle

Appendix 2

Activation and deactivation mechanisms of the counter(s), warning system, operability restriction, service mode in case of HDDF engines and vehicles - Description and illustrations

A.2.1. DESCRIPTION of the COUNTER MECHANISM

A.2.1.1. General

A.2.1.1.1. To comply with the requirements of this annex, the system shall contain a counter to record the number of hours during which the engine has been operated while the system has detected a malfunctioning gas supply.

A.2.1.1.2. This counter shall be capable of counting up to 30 minutes operating time. The counter intervals shall be no longer than 3 minutes. When reaching its maximum value permitted by the system, it shall hold that value unless the conditions allowing the counter to be reset to zero are met.

A.2.1.2. Principle of the counter mechanism

A.2.1.2.1. The counters shall operate as follows:

A.2.1.2.1.1. If starting from zero, the counter shall begin counting as soon as a malfunctioning gas supply is detected according to paragraph 7.2 of this Annex and the corresponding diagnostic trouble code (DTC) has the status confirmed and active.

A.2.1.2.1.2. The counter shall halt and hold its current value if a single monitoring event occurs and the malfunction that originally activated the counter is no longer detected or if the failure has been erased by a scan tool or a maintenance tool.

A.2.1.2.1.2.1. The counter shall also halt and hold its current value when the service mode becomes active.

A.2.1.2.1.3. Once frozen, the counter shall be reset to zero and restart counting if a malfunction relevant to that counter is detected and the service mode activated.

A.2.1.2.1.3.1. Once frozen, the counter shall also be reset to zero when the monitors relevant to that counter have run at least once to completion of their monitoring cycle without having detected a malfunction and no malfunction relevant to that counter has been detected during 36 engine operating hours since the counter was last held.

A.2.1.3. Illustration of the counter mechanism

Figure A2.1 gives via three use–cases an illustration of the counter mechanism

A.2.1.3.1. Use-case 1:
A malfunction of the gas supply is detected for the very first time.

The service mode is activated and the counter starts counting once the DTC gets the "confirmed and active" status (2nd detection).
The vehicle encounters a stand-still situation before reaching 30 minutes operating time after the service mode is activated.
The service mode becomes active and the vehicle speed is limited to 20 km/h (see paragraph 4.2.2.1. of this Annex).
The counter freezes at its present value.

A.2.1.3.2. Use-case 2:
A malfunction of the gas supply is detected while the gas supply malfunction counter is not at zero (in this use-case it indicates the value it reached in use-case 1 when the vehicle became standstill).
The service mode is activated and the counter restarts counting from zero as soon as the DTC gets the "potential" status (1st detection: see paragraph 4.2.3.2.1. of this Annex).
After 30 minutes of operation without a standstill situation, the service mode becomes active and the vehicle speed is limited to 20 km/h (see paragraph 4.2.2.1 of this Annex).
The counter freezes at a value of 30 minutes operating time.

A.2.1.3.3. Use-case 3:
After 36 operating hours without detection of a malfunction of the gas supply, the counter is reset to zero (see paragraph A.2.1.2.3.2.1).
A malfunction of the gas supply is again detected while the gas supply malfunction counter is at zero (1st detection).
The service mode is activated and the counter starts counting once the DTC gets the "confirmed and active" status (2nd detection).
After 30 minutes of operation without a standstill situation, the service mode becomes active and the vehicle speed is limited to 20 km/h (see paragraph 4.2.2.1 of this Annex).
The counter freezes at a value of 30 minutes operating time.

A.2.2. ILLUSTRATION OF THE OTHER ACTIVATION AND DEACTIVATION MECHANISMS

A.2.2.1. Empty gas tank
Figure A2.2 gives an illustration of the events occurring in the case of a HDDF vehicle when a gas tank becomes empty through one typical use-case.

In that use case,
- The warning system specified in paragraph 0. of this Annex becomes active when the level of gas reaches the critical level defined by the manufacturer.
- The service mode is activated (in the case of a Type A HDDF) or the engine switches to Diesel mode (in the case of a Type B HDDF).
- In the case of a Type A HDDF, the service mode becomes active and the vehicle speed is limited to 20 km/h after the next time the vehicle is stationary

or after 30 minutes operating time without standstill (see paragraph 4.2.2.1 of this Annex).
- The gas tank is refilled.
- The vehicle operates again in dual-fuel mode as soon as the tank is refilled above the critical level.

A.2.2.2. Malfunctioning gas supply

Figure A2.3 gives via one typical use-case an illustration of the events occurring in the case of a malfunction of the gas supply system. This illustration should be understood as complementary to that given in section A.2.1 and dealing with the counter mechanism.

In that use case,
- The failure of the gas supply system occurs for the very first time. The DTC gets the potential status (1st detection).
- The service mode is activated (in the case of a Type A HDDF) or the engine switches to Diesel mode (in the case of a Type B HDDF) as soon as the DTC gets the "confirmed and active" status (2nd detection).
- In the case of a Type A HDDF, the service mode becomes active and the vehicle speed is limited to 20 km/h after the next time the vehicle is stationary or after 30 minutes operating time without standstill (see paragraph 4.2.2.1 of this Annex).
- The vehicle operates again in dual-fuel mode as soon as the failure is repaired.

A.2.2.3. Abnormality of the gas consumption

Figure A2.4 gives via one typical use-case an illustration of the events occurring in the case of an abnormality of the gas consumption.

In that use case,
- The service mode is activated (in the case of a Type A HDDF) or the engine switches to Diesel mode (in the case of a Type B HDDF) as soon as the DTC gets the "potential" status (1st detection).
- In the case of a Type A HDDF, the service mode becomes active and the vehicle speed is limited to 20 km/h after the next time the vehicle is stationary or after 30 minutes operating time without standstill (see paragraph 4.2.2.1 of this Annex).
- The vehicle operates again in dual-fuel mode as soon as the abnormality is rectified.

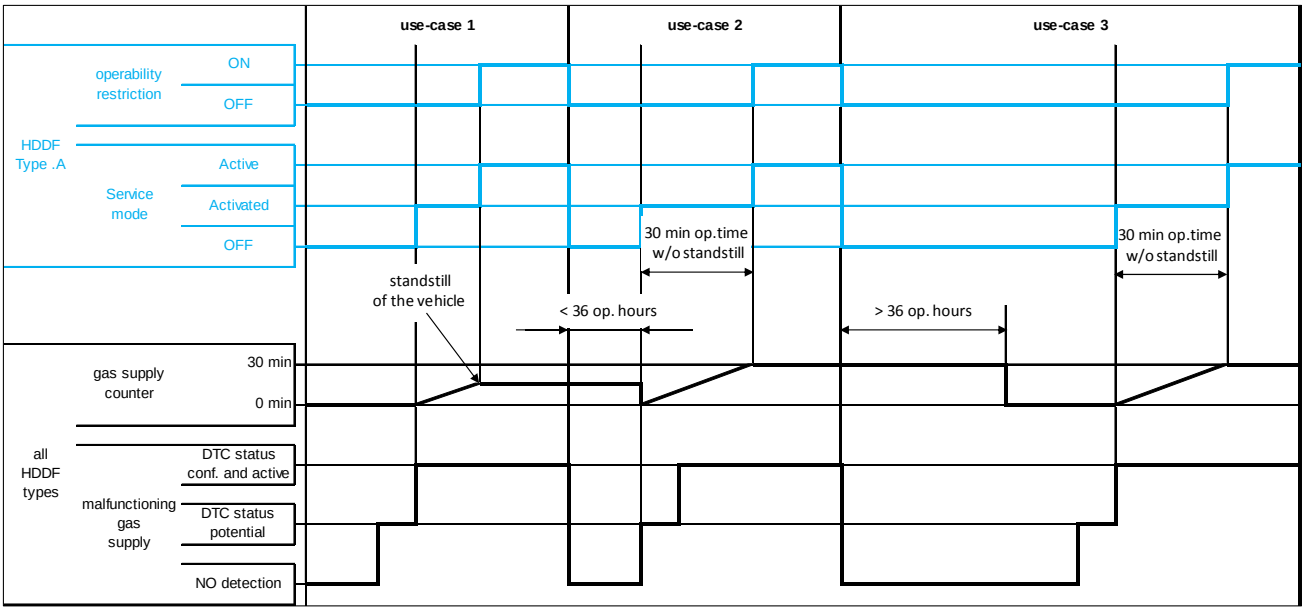

Figure A2.1 – Illustration of the gas supply counter mechanism (Type A HDDF - 3 use-cases)

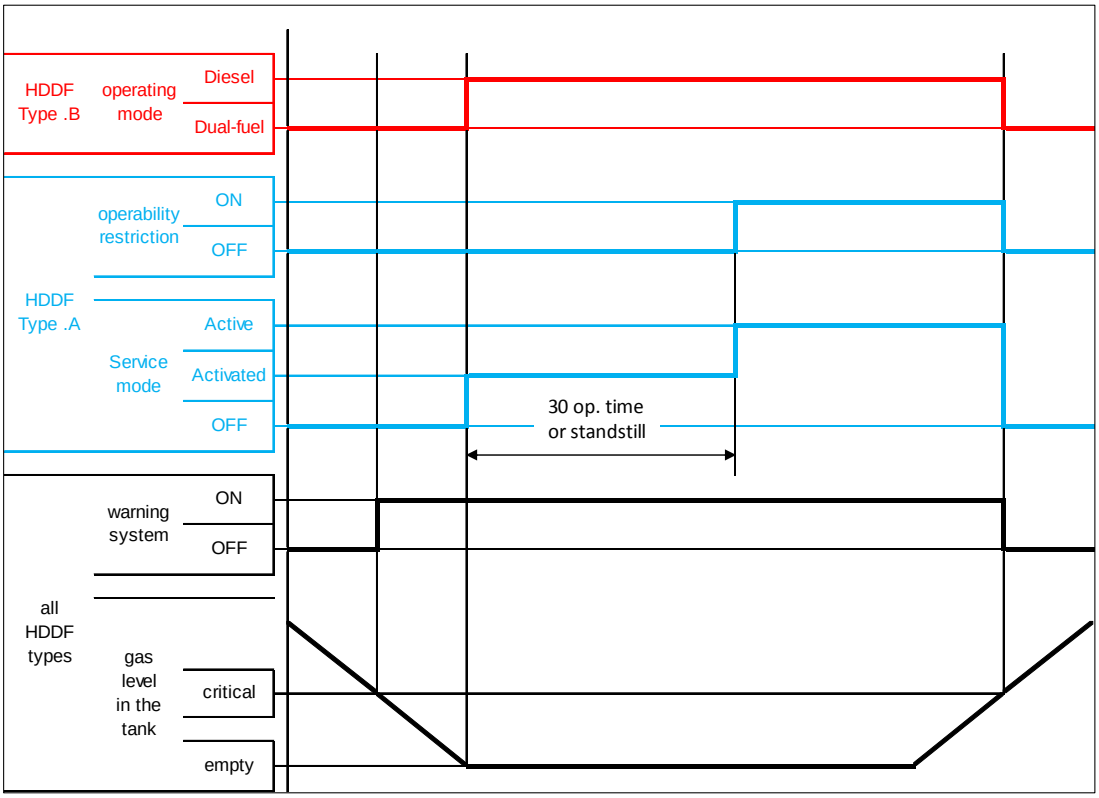

Figure A2.2 – Illustration of the events occurring in case of an empty gas tank
(Types A and B HDDF)

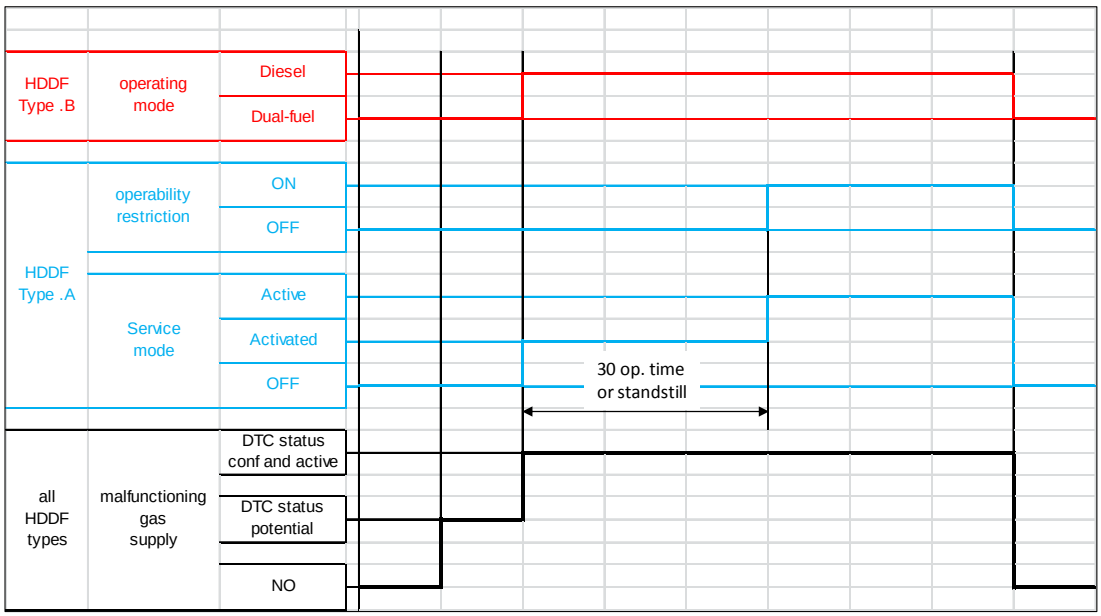

Figure A2.3 – Illustration of the events occurring in case of a malfunctioning gas supply system (Types A and B HDDF)

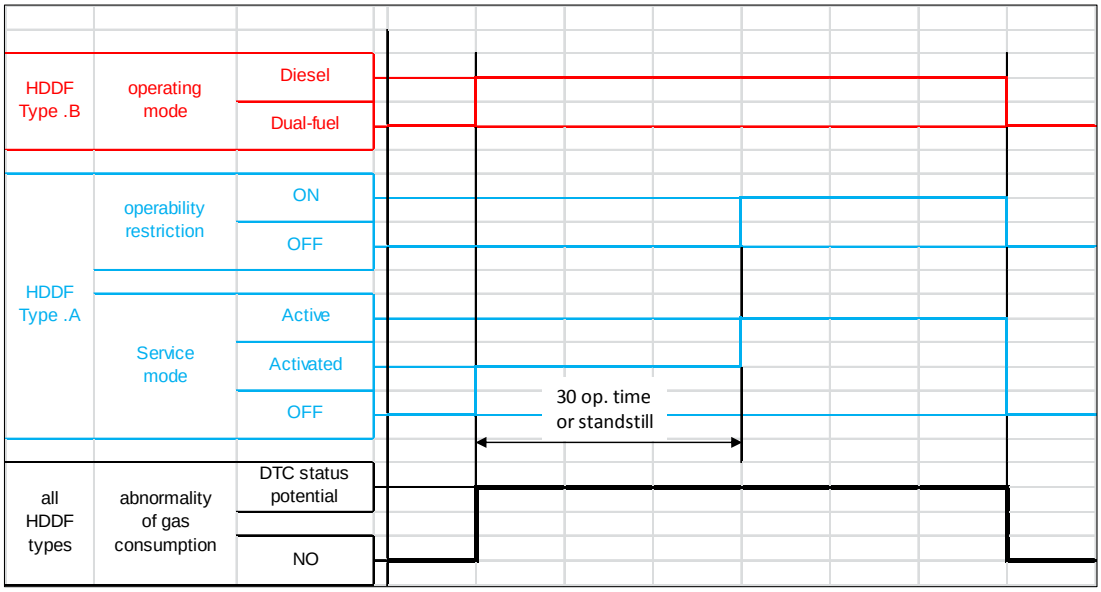

Figure A2.4 – Illustration of the events occurring in case of abnormality of gas consumption (Types A and B HDDF)

Appendix 3

HDDF dual-fuel indicator, warning system, operability restriction - Demonstration requirements

A.3.1. DUAL-FUEL INDICATORS

[To be finalised through an informal document to be submitted by GFV in due time for the 64th session of the GRPE]

[A.3.1.1. Dual-fuel mode indication

A.3.1.2. Diesel mode indication

A.3.1.3. Service mode indication

A.3.2. WARNING SYSTEM

A.3.3. OPERABILITY RESTRICTION]

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Appendix 4

Additional emission test procedure requirements for dual-fuel engines

A.4.1. GENERAL

This appendix defines the additional requirements and exceptions to Annex 4 of this regulation to enable emission testing of dual-fuel engines.

Emission testing of a dual-fuel engine is complicated by the fact that the fuel used by the engine can vary between pure diesel fuel and a combination of mainly gaseous fuel with only a small amount of diesel 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.

[To be finalised through an informal document to be submitted by GFV in due time for the 64th session of the GRPE]

Appendix 5

Additional PEMS emission test procedure requirements for dual-fuel engines

A.5.1 GENERAL

This appendix defines the additional requirements and exceptions to Annex 8 of this regulation to enable PEMS emission testing of dual-fuel engines.

Emission testing of a dual fuel engine is complicated by the fact that the fuel used by the engine can vary between pure diesel fuel and a combination of mainly gaseous fuel with only a small amount of diesel 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.

[To be finalised through an informal document to be submitted by GFV in due time for the 64th session of the GRPE]

Appendix 6

Determination of α and u_{gas} values for dual-fuel engines

A.6.1. GENERAL

This appendix defines the determination of α and u_{gas} values for the dry-wet factor and emissions calculations for emission testing of dual-fuel engines.

[To be finalised through an informal document to be submitted by GFV in due time for the 64th session of the GRPE]