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**Economic Commission for Europe****Inland Transport Committee****World Forum for Harmonization of Vehicle Regulations****Working Party on Pollution and Energy****Ninetieth session**

Geneva, 9–12 January 2024

Item 6 (a) of the provisional agenda

**Agricultural and forestry tractors, non-road mobile machinery:****UN Regulations Nos. 96 (Diesel emission (agricultural tractors)) and****120 (Net power of tractors and non-road mobile machinery)**

**Proposal for a new Supplement to the 05 series of amendments to UN Regulation No. 96 (Uniform provisions concerning the approval of engines to be installed in agricultural and forestry tractors and in nonroad mobile machinery with regard to the emissions of pollutants by the engine)**

**Submitted by the expert from Euromot \***

The text reproduced below was prepared by the experts from the European Association of Internal Combustion Engine Manufacturers (EUROMOT). This document fixes spelling and typographic errors, as well as aiming to permit the use of hydrogen (H<sub>2</sub>) as fuel for approval of internal combustion engines to be installed in agricultural and forestry tractors and in non-road mobile machinery, with regard to the emissions of pollutants by the engine. The modifications to the current text of the Regulation are marked in bold for new or strikethrough for deleted characters.

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\* In accordance with the programme of work of the Inland Transport Committee for 2023 as outlined in proposed programme budget for 2024 (A/78/6 (Sect. 20), table 20.5), the World Forum will develop, harmonize and update UN Regulations in order to enhance the performance of vehicles. The present document is submitted in conformity with that mandate.



## I. Proposal

*Paragraph 1.1.3.*, amend to read:

“1.1.3. "Category NRSh": hand-held ~~Spark~~ **Spark** Ignition (SI) engines having a reference power that is less than 19 kW, exclusively for use in hand-held machinery;”

*Insert new Paragraph 3.1.1.* to read:

**“3.1.1. In the case of an application for type approval of engines operated solely on hydrogen, hydrogen shall be the fuel the engine is designed to operate on primarily. Requirements for dual-fuel hydrogen engines have not yet been established under this regulation.**”

*Paragraph 5.1.1.*, amend to read:

“5.1.1.1. For this purpose, the engine final emission test result calculated according to the requirements of paragraph 5.1.2. shall not exceed the exhaust emission limits set out in Appendix 2 to this Regulation, when:

- (a) Tested in accordance with the test conditions and detailed technical procedures set out in Annex 4 to this Regulation,
- (b) Using the fuel(s) ~~specifiend~~ in paragraph 5.1.3.
- (c) Using the test cycles specified in Appendix A.6 to Annex 4 to this Regulation.”

*Paragraph 5.1.3.*, amend to read:

“5.1.3. In accordance with Appendix 4 to this Regulation, the testing of an engine type or engine family to determine whether it meets the emission limits set out in this Regulation shall be carried out by using the following reference fuels or fuel combinations, as appropriate:

- (a) Diesel;
- (b) Petrol;
- (c) Petrol/oil mixture, for two stroke SI engines;
- (d) Natural gas/bio methane;
- (e) Liquid petroleum gas (LPG);
- (f) Ethanol;
- (g) Hydrogen.**

The engine type or engine family shall, in addition, meet the exhaust emission limits set out in this Regulation in respect of any other specified fuels, fuel mixtures or fuel emulsions included by a manufacturer in an application for type approval and described in the Appendix 4 to this Regulation.

*Paragraph 5.6.4.*, amend to read:

“5.6.4. Test requirements

The test shall be carried out immediately after the applicable NRSC as follows:

- (a) The test of the randomly selected torque and engine speed points shall either be carried out immediately after the discrete-mode NRSC test sequence described in sub-paragraphs (a) to (e) of paragraph 7.8.1.2. of Annex 4 but before the post test procedures (f) or after the Ramped Modal non-road steady-state test Cycle ("RMC") test sequence described in sub-paragraphs (a) to (d) of paragraph 7.8.2.3. of Annex 4 but before the post test procedures (e) as relevant;
- (b) The tests shall be carried out as required in sub-paragraphs (b) to (e) of paragraph 7.8.1.2. of Annex 4 using the multiple filter method (one filter for each test point) for each of the test points chosen in accordance with paragraph 3.;

- (c) A specific emission value shall be calculated (in g/kWh or #/kWh as applicable) for each test point;
- (d) **For engines operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4., emissions values shall be calculated using Annex 11. For engines operated on all other fuels, emissions values** may be calculated on a mass basis using Appendix A.1. of Annex 5 or on a molar basis using Appendix A.2. of Annex 5. **In all cases, the method used ~~but~~** shall be consistent with the method used for the discrete mode NRSC or RMC test-;
- (e) For gaseous and PN, if applicable, summation calculations,  $N_{mode}$  in equation (A.5-64) or (A.5-136) and (A.5-180) shall be set to 1 and a weighting factor of 1 shall be used;
- (f) For particulate calculations the multiple filter method shall be used; for summation calculations,  $N$  in equation (A.5-67) shall be set to 1 and a weighting factor of 1 shall be used.

Paragraph 6.1.4., amend to read:

- “6.1.4. **For engines other than those operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4. Manufacturers** shall make available to OEMs the value of the carbon dioxide (CO<sub>2</sub>) emissions determined during the type-approval process and shall instruct the OEMs to communicate that information, together with explanatory information on the test conditions, to the end-user of the non-road mobile machinery or category T vehicle in which the engine is intended to be installed. **For engines operated solely on hydrogen as specified in Appendix 4 Paragraph A.4.4., it is not required to make this value available to the OEM.”**

Paragraph 8.7.2.3., amend to read:

- “8.7.2.3. Engines shall be subjected to emissions testing in accordance with the requirements of Annex 4, or, in the case of dual-fuel engines, in accordance with Annex 7, **or, in the case of engine operated solely on hydrogen, in accordance with Annex 11**, and shall be subject to the test cycles relevant for the engine type in accordance with Appendix A.6 to Annex 4.”

Paragraph 8.7.4., amend to read:

- “8.7.4. All these tests may be conducted with the applicable market fuels. However, at the manufacturer’s request, the reference fuels described in ~~Appendix 5~~ **Annex 6** to this Regulation shall be used. For gaseous fuelled engines this means that tests shall be performed with at least two of the reference fuels for each gaseous-fuelled engine, except in the case of a gaseous-fuelled engine with a fuel-specific type-approval where only one reference fuel is required, as described in Appendix 4 to this Regulation. Where more than one gaseous reference fuel is used the results shall demonstrate that the engine meets the limit values with each fuel.”

Appendix 4 insert new paragraphs to read:

- A.4.4. Requirements for an engine operated solely on hydrogen**
- A.4.4.1. The engine manufacturer shall not indicate at any time that an engine type or engine family may be operated in the territory of any Contracting Party on market fuels other than those that comply with grade D of ISO standard ISO 14687:2019 unless the manufacturer additionally complies with the requirement in paragraph A.4.4.2..**
- A.4.4.2. If the manufacturer permits engines to run on additional market fuels other than those identified in paragraph A.4.4.1., such as running on other grades of hydrogen, all of the following actions shall be taken by the manufacturer:**

- (a) Declare, in the information document set out in Annex 1A, the specification of the market fuels on which the engine family is capable to run;
- (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 monitoring set out by any Contracting Party, if any, on the fuels declared and the applicable market fuel identified in paragraph A.4.4.1.

**A.4.4.3. In order to receive a type-approval of an engine operated solely on hydrogen, the manufacturer shall comply with the requirements set out in Annex 11.”**

Appendix 5 Paragraph A.5.6., amend to read:

“A.5.6. **For engines other than those operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4.** ¶the manufacturer shall provide to the OEM the value of the carbon dioxide (CO<sub>2</sub>) emissions in g/kWh determined during the type-approval process and recorded in the engine communication. This value shall be provided by the OEM to the end-users accompanied by the following statements: *‘This CO<sub>2</sub> emission value results from testing over a fixed test cycle under laboratory conditions of an (a parent) engine representative of the engine type (engine family) and shall not imply or express any guarantee of the performance of a particular engine once installed in a type of non-road mobile machinery or category T vehicle’.* **For engines operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4., the manufacturer is not required to provide a value of the carbon dioxide (CO<sub>2</sub>) emissions to the OEM. In this case the statement provided by the OEM to the end-user shall be: ‘A CO<sub>2</sub> emission value has not been declared, because the engine has been type-approved to solely operate on hydrogen (H<sub>2</sub>).’.**”

Annex 1 Appendix A.3 Paragraph 2.8.1., amend to read:

“2.8.1. Fuel Type: Diesel (non-road gas-oil)/Ethanol for dedicated compression ignition engines (ED95)/Petrol (E10)/ Ethanol (E85)/(Natural gas/Biomethane)/Liquid Petroleum Gas (LPG)/ **Hydrogen**”

Annex 1 Appendix A.3 Paragraph 3.14.1., amend to read:

3.14.1.	Fuel: LPG /NG-H/NG-L /NG-HL/LNG/Fuel specific LNG/ <b>Hydrogen</b>					
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Annex 2 Part A Paragraph 2.8.1., amend to read:

“2.8.1. Fuel Type(s): Diesel (non-road gas-oil)/Ethanol for dedicated compression ignition engines (ED95)/Petrol (E10)/ Ethanol (E85)/(Natural gas/Biomethane)/Liquid Petroleum Gas (LPG)/ **Hydrogen**”

Annex 2 Part B Paragraph 11.2., amend to read:

“11.2. CO<sub>2</sub> result<sup>5</sup>:”

Annex 2 Part B Paragraph 11.3.2., amend to read:

“11.3.2. NRTC reference CO<sub>2</sub> (g)<sup>5</sup>:”

Annex 2 Part B Explanatory note to Annex 2, amend to read:

“Explanatory notes to Annex 2

(Footnote markers, footnotes and explanatory notes not to be stated on the type-approval certificate)

- <sup>1</sup> The distinguish numbers of the Contracting Parties to the 1958 Agreement are reproduced in Annex 3 to the Consolidated Resolution on the Construction of Vehicles (R.E.3), document ECE/TRANS/WP.29/78/Rev.6 - [www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html](http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29resolutions.html)
- <sup>2</sup> Strike out the unused options, or only show the used option(s).
- <sup>3</sup> Indicate the applicable option for the category and sub-category in accordance with entry 1.7. of the information document set out in Part A of Appendix A.3 to Annex 1.
- <sup>4</sup> Indicate the used test cycle as prescribed in Appendix A.6 to Annex 4 to this Regulation.
- <sup>5</sup> **Not mandatory for engines operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4.”**

*Annex 2 Appendix A.1 Paragraph A.1.3., TEST REPORT FOR NON-ROAD ENGINES*, insert new Paragraphs to read:

**“4.5. Hydrogen**

**4.5.1. Make:**.....

**4.5.2. Type:**.....

**4.56.** Dual-fuel engine (in addition to relevant sections above)

**4.56.1.** Gas energy ratio on test cycle: .....

*Annex 2 Appendix A.1 Paragraph 9.3.3.*, amend to read:

“9.3.3. Cycle weighted CO<sub>2</sub> (g/kWh) <sup>(7)</sup>.”

*Annex 2 Appendix A.1 Paragraph 10.3.1.*, amend to read:

“10.3.1. Cycle weighted CO<sub>2</sub> (g/kWh) <sup>(7)</sup>.”

*Annex 2 Appendix A.1 Paragraph 10.3.4.*, amend to read:

“10.3.4. Cycle weighted CO<sub>2</sub> (g/kWh) <sup>(7)</sup>.”

*Annex 2 Appendix A.1, Paragraph 10.4.1.*, amend to read:

“10.4.1. Cycle CO<sub>2</sub> (g/kWh) <sup>(7)</sup>.”

*Annex 2 Appendix A.1, Paragraph 10.4.4.*, amend to read:

“10.4.4. Cycle CO<sub>2</sub> (g)<sup>(7)</sup>.”

*Annex 2 Appendix A.1, Paragraph 11.2.*, amend to read:

“11.2. CO<sub>2</sub> result <sup>(4)</sup>(<sup>7</sup>):”

*Annex 2 Appendix A.1, Paragraph 11.3.2.*, amend to read:

“11.3.2. NRTC reference CO<sub>2</sub> (g)<sup>(6)</sup>(<sup>7</sup>):”

*Annex 2 Appendix A.1 Explanatory notes to the test report template*, amend to read:

“Explanatory notes to the test report template

(Footnote markers, footnotes and explanatory notes not to be stated on the test report)

- <sup>(1)</sup> For NRSC note the cycle indicated in paragraph 9.1.; for transient test note cycle indicated in paragraph 10.1.
- <sup>(2)</sup> Copy the results from table 6
- <sup>(3)</sup> Copy the results from table 9 or 10, as applicable

- (4) For an engine type or engine family that is tested on both the NRSC and a transient cycle, indicate the hot cycle CO<sub>2</sub> emissions values from the NRTC noted in paragraph 10.2.3. or the CO<sub>2</sub> emissions values from the LSI-NRTC noted in paragraph 10.3.3. For an engine only tested on an NRSC indicate the CO<sub>2</sub> emissions values given in that cycle from paragraph 9.3.3.
- (5) Where engine is tested on NRTC record value from 10.3.3., otherwise leave blank
- (6) Where engine is tested on NRTC record value from 10.3.4., otherwise leave blank
- (7) **Not mandatory for engines operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4.”**

Annex 3 Appendix A.1, Table 2 amend to read:

“Engine Fuel type (column 1)	Sub-type, where applicable (column 2)	Fuel Type Code (column 3)
Diesel (non-road gas-oil) fuelled CI engine		D
Dedicated Ethanol (ED95) fuelled CI engine		ED
Ethanol (E85) fuelled SI engine		E85
Petrol (E10) fuelled SI engine		P
LPG fuelled SI engine		Q
Natural gas/biomethane fuelled SI engine	Engine approved and calibrated for the H-range of gases	H
	Engine approved and calibrated for the L-range of gases	L
	Engine approved and calibrated for both the H-range and L-range of gases	HL
	Engine 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	HT
	Engine 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	LT
	Engine 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	HLT

	Engine approved and calibrated for a specific liquefied natural gas / liquefied biomethane composition resulting in a $\lambda$ -shift factor not differing by more than 3 percent the $\lambda$ -shift factor of the G20 gas specified in Appendix 4 to this Regulation, and the ethane content of which does not exceed 1.5 percent	LN2
	Engine approved and calibrated for any other (than above) liquefied natural gas / liquefied biomethane composition.	LNG
Dual-fuel engines	for dual-fuel engines of Type 1A	1A#(*)
	for dual-fuel engines of Type 1B	1B#(*)
	for dual-fuel engines of Type 2A	2A#(*)
	for dual-fuel engines of Type 2B	2B#(*)
	for dual-fuel engines of Type 3B	3B#(*)
Engine solely fuelled on Hydrogen	<b>SI engine being approved and calibrated for gaseous hydrogen<sup>1</sup></b>	<b>T</b>
	<b>CI engine approved and calibrated for gaseous hydrogen<sup>1</sup></b>	<b>TD</b>
	<b>SI engine being approved and calibrated for liquified hydrogen<sup>1</sup></b>	<b>U</b>
	<b>CI engine being approved and calibrated for liquified hydrogen<sup>1</sup></b>	<b>UD</b>

(\*) Replace '#' with approved gas specification from Table 3.

(<sup>1</sup>) **Independent of whether this gaseous fuel is stored in a compressed or liquified state**"

Annex 4 Paragraph 5.1.2., amend to read:

“5.1.2. Emissions of gaseous and particulate pollutants

The pollutants are represented by:

- (a) Oxides of nitrogen, NO<sub>x</sub>;
- (b) Hydrocarbons, which are expressed as total hydrocarbons, HC (or THC);
- (c) Particulate matter, PM;
- (d) Particle number, PN<sub>r</sub>;
- (e) Carbon monoxide, CO.

The measured values of gaseous and particulate matter pollutants exhausted by the engine refer to the brake-specific emissions in grams per kilowatt-hour (g/kWh), while for particulate number the measured values refers to the brake-specific emissions in number of particles per kilowatt-hour (#/kWh). Other system of units may be used with appropriate conversion.

The gaseous and particulate pollutants that shall be measured are those for which limit values are applicable to the engine sub-category being tested as set out in Appendix 2 to this Regulation.

**Brake specific emissions shall be determined using Annex 11 for engines operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4., and determined using Annex 5 for engines operated on all other fuels, fuel mixtures or emulsions.**

The results determined as set out in paragraph 5.1 of this Regulation shall not exceed the applicable limit values.

The CO<sub>2</sub> emission values shall be measured and reported for all engine sub-categories as **where** required by paragraph 6.1.4. of this Regulation-

The mean emission of ammonia (NH<sub>3</sub>) shall additionally be measured, as required in accordance with paragraph 3.4. of Annex 9, when the NO<sub>x</sub> control measures that are part of the engine emission control system, include use of a reagent and shall not exceed the values set out in that paragraph.

The emissions shall be determined on the duty cycles (steady-state and/or transient), as described in paragraph 7 of this Annex. The measurement systems shall meet the calibration and performance checks set out in paragraph 8 of this Annex. with the measurement equipment described in paragraph 9 of this Annex. **For engines operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4. the requirements set out in Annex 11 shall additionally apply.**

Other systems or analysers may be approved by the Type Approval Authority if it is found that they yield equivalent results in accordance with paragraph 5.1.3 of this Annex.”

*Annex 4, Paragraph 8.1.9.2.3., amend to read:*

“8.1.9.2.3. System requirements

A CO NDIR analyser shall have combined H<sub>2</sub>O and CO<sub>2</sub> interference that is within  $\pm 2$  per cent of the expected mean concentration of CO, **or 20ppm, whichever is larger.**”

*Annex 4 Paragraph 9.4.10., amend to read:*

9.4.10. Air-to-fuel ratio measurements

A Zirconia (ZrO<sub>2</sub>) analyser may be used to measure air-to-fuel ratio in raw exhaust for continuous sampling. O<sub>2</sub> measurements with intake air or fuel flow measurements may be used to calculate exhaust flow rate according to Annex 5.

**The sensor shall be mounted directly on the exhaust pipe where the exhaust gas temperature is high enough to eliminate water condensation.**

**The accuracy of the sensor with incorporated electronics shall be as follows:**

- (a)  $\pm 3\%$  of reading for  $\lambda < 2$ ;
- (b)  $\pm 5\%$  of reading for  $2 \leq \lambda < 5$ ;
- (c)  $\pm 10\%$  of reading for  $5 \leq \lambda$ .

**To fulfil the accuracy specified above, the sensor shall be calibrated as specified by the instrument manufacturer.”**



Annex 5 Title, amend to read:

## “Annex 5

### Method for data evaluation and calculation for engines other than those operated solely on hydrogen”

Annex 5, paragraph 1., amend to read:

“1. General requirements

**For engines other than those operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4.,** calculation of emissions shall be performed according to either Appendix A.1 (mass based calculations) or Appendix A.2 (molar based calculations). Mixture between the two methods is not permitted. It shall not be required to perform the calculations according to both Appendix A.1 and Appendix A.2.

The specific requirements for particle number (PN) measurement, where applicable, are laid down in Appendix A.6.”

Annex 5, Appendix A.1, paragraph A.1.1.6.3., amend to read:

“A.1.1.3. Dry-to-wet concentration conversion

If the emissions are measured on a dry basis, the measured concentration  $c_d$  on dry basis shall be converted to the concentration  $c_w$  on a wet basis by means of equation (A.5-3). **If water injection is used, Equations (A.5-4) and (A.5-7) are not applicable.**”

Annex 5, Appendix A.1, paragraph A.1.1.6.3., amend to read:

“A.1.1.6.3. Air flow and air to fuel ratio measurement method

This involves exhaust mass calculation from the air flow and the air to fuel ratio. The instantaneous exhaust gas mass flow  $q_{mew,i}$  [kg/s] shall be calculated by means of equation (A.5-17):

$$q_{mew,i} = q_{maw,i} \cdot \left( 1 + \frac{1}{A/F_{st} \cdot \lambda_i} \right) \quad (A.5-17)$$

with:

$$A/F_{st} = \frac{138.0 \cdot \left( 1 + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma \right)}{12.011 + 1.00794 \cdot \alpha + 15.9994 \cdot \varepsilon + 14.0067 \cdot \delta + 32.065 \cdot \gamma} \quad (A.5-18)$$

$$\lambda_i = \frac{\left( 100 - \frac{c_{COd} \cdot 10^{-4}}{2} - c_{HCw} \cdot 10^{-4} \right) + \left( \frac{\alpha}{4} \cdot \frac{1 - \frac{2 \cdot c_{COd} \cdot 10^{-4}}{3.5 \cdot c_{CO2d}} - \frac{\varepsilon}{2} - \frac{\delta}{2}}{1 + \frac{c_{COd} \cdot 10^{-4}}{3.5 \cdot c_{CO2d}}} \right) \cdot (c_{CO2d} + c_{COd} \cdot 10^{-4})}{4.764 \cdot \left( 1 + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma \right) \cdot (c_{CO2d} + c_{COd} \cdot 10^{-4} + c_{HCw} \cdot 10^{-4})} \quad (A.5-19)$$

where:

$q_{maw,i}$  = wet intake air mass flow rate [kg/s]

$A/F_{st}$  = stoichiometric air-to-fuel ratio [-]

$\lambda_i$	= instantaneous excess air ratio <b>calculated by Equation (A.5-19) or measured by a lambda sensor</b> [-]
$c_{COd}$	= concentration of CO in the raw exhaust gas on a dry basis [ppm]
$c_{CO2d}$	= concentration of CO <sub>2</sub> in the raw exhaust gas on a dry basis [per cent]
$c_{HCw}$	= concentration of HC in the raw exhaust gas on a wet basis [ppm C1]
$\alpha$	= molar hydrogen-to-carbon ratio [-]
$\delta$	= molar nitrogen-to-carbon ratio [-]
$\varepsilon$	= molar oxygen-to-carbon ratio [-]
$\gamma$	= atomic sulphur-to-carbon ratio [-]”

Annex 6. insert new paragraph to read:

**“3.3. Type: Hydrogen**

<i>Parameter</i>	<i>Unit</i>	<i>Limits</i>		<i>Test method</i>
		<i>Minimum</i>	<i>Maximum</i>	
Hydrogen fuel index	%	99.97		1
Total non-hydrogen gases	µmol/mol		300	
Lists of non-hydrogen gases and the specification of each contaminant <sup>6</sup> :				
Water (H <sub>2</sub> O)	µmol/mol		5	5
Total hydrocarbons except methane (C1 equivalent) <sup>2</sup>	µmol/mol		2	5
Methane (CH <sub>4</sub> )	µmol/mol		100	5
Oxygen (O <sub>2</sub> )	µmol/mol		5	5
Helium (He)	µmol/mol		300	5
Nitrogen (N <sub>2</sub> )	µmol/mol		300	5
Argon (Ar)	µmol/mol		300	5
Carbon dioxide (CO <sub>2</sub> )	µmol/mol		2	5
Carbon monoxide (CO) <sup>3</sup>	µmol/mol		0.2	5
Total sulphur compounds (H <sub>2</sub> S basis) <sup>4</sup>	µmol/mol		0.004	5
Formaldehyde (HCHO)	µmol/mol		0.2	5
Formic acid (HCOOH)	µmol/mol		0.2	5
Ammonia (NH <sub>3</sub> )	µmol/mol		0.1	5
Total halogenated compounds (Halogenate ion basis)	µmol/mol		0.05	5

*Notes:*

- <sup>1</sup> The hydrogen fuel index is determined by subtracting the “total non-hydrogen gases” in this table, expressed in mole per cent, from 100 mole per cent.
- <sup>2</sup> Total hydrocarbons except methane include oxygenated organic species.
- <sup>3</sup> The sum of measured CO, HCHO and HCOOH shall not exceed 0.2 µmol/mol
- <sup>4</sup> As a minimum, total sulphur compounds include H<sub>2</sub>S, COS, CS<sub>2</sub> and mercaptans, which are typically found in natural gas.
- <sup>5</sup> Test method shall be documented. Test methods defined in ISO21087 are preferable.
- <sup>6</sup> The analysis of specific contaminants depending on the production process shall be exempted. The manufacturer shall provide the approval authority reasons for exempting specific contaminants.”

Annex 7, Appendix A.2, paragraph A.2.1., amend to read:

“A.2.1. General

This Appendix defines the additional requirements and exceptions to enable emission testing of dual-fuel engines independent whether these emissions are solely exhaust emissions or also crankcase emissions added to the exhaust emissions according to paragraph 6.10. of Annex 4. In the case that no additional requirement or exception is listed, the requirements of this Regulation shall apply to dual-fuel engines in the same way as they apply to any other approved engine types or engine families.

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

**This Appendix is not applicable if one of the fuels used in a dual fuel engine is hydrogen.”**

Annex 10, paragraph 2.4.6., amend to read:

“2.4.6. Fuel type

- (a) Diesel (non-road gas-oil);
- (b) Ethanol for dedicated compression ignition engines (ED95);
- (c) Petrol (E10);
- (d) Ethanol (E85);
- (e) Natural gas/Biomethane:
  - (i) Universal fuel — high calorific fuel (H-gas) and low calorific fuel (L-gas);
  - (ii) Restricted fuel — high calorific fuel (H-gas);
  - (iii) Restricted fuel — low calorific fuel (L-gas);
  - (iv) Fuel specific (LNG);
- (f) Liquid Petroleum Gas (LPG);
- (g) **Hydrogen.”**

*Insert new Annex 11, to read:*

## **“Annex 11**

### **Technical requirements for engines operated solely on hydrogen**

1. **Scope**

This Annex defines the additional requirements and exceptions to enable emission testing of engines operated solely on hydrogen as specified in Appendix 4 paragraph A.4.4. independent of whether these emissions are solely exhaust emissions or also crankcase emissions added to the exhaust emissions according to paragraph 6.10. of Annex 4. In the case that no additional requirement or exception is listed, the requirements of this Regulation shall apply to engines operated solely on hydrogen in the same way as they apply to any other approved engine types or engine families.
2. **General requirements**

Paragraph 5. of Annex 4 shall apply.
3. **Test conditions**

Paragraph 6. of Annex 4 shall apply.
4. **Test procedures**

Paragraph 7. of Annex 4 shall apply except as set out in paragraph 4.1
- 4.1. **The total mass of each gaseous constituent shall be determined over the applicable test cycle using continuous sampling where the constituent’s concentration is measured continuously from raw exhaust.**
5. **Measurement procedures**

Paragraph 8. of Annex 4 shall apply except as set out in paragraph 5.1.
- 5.1. **The emissions measurement system shall comply with the calibration and performance checks at the highest exhaust water content expected during emission testing. In particular it shall be ensured that the temperatures of all sample gas carrying components of the emission measurement system, except for sample dryers, remain at least 10 K above the dew point of the sample gas at the corresponding location.**
6. **Measurement equipment**

Paragraph 9. of Annex 4 shall apply except as set out in paragraph 6.1 of this Annex.
- 6.1. **The dilution procedure set out in paragraph 9.2. of Annex 4 shall not apply to gaseous emissions measurements.**
7. **Particle number emissions measurement**

Appendix A.1 to Annex 4 shall apply.
8. **Emissions Calculation**

The emissions calculation shall be performed according to Annex 5 Appendix A.1. (mass based emissions calculations) except as set out in paragraphs 8.1. to 8.5. of this Annex.
- 8.1. **The measurement of gaseous emissions shall be conducted from raw exhaust gas according to Annex 5 Appendix A.1 paragraph A.1.1..**
- 8.2. **Dry-to-wet concentration conversion**

If the emissions are measured on a dry basis, Equation A.5-7 shall not be used for engines operated solely on hydrogen.

### 8.3. Component specific factor $u$

Equation A.5-11 shall not be used to calculate  $u$  values for engines operated solely on hydrogen. The values in Table A.11.1. may be used for the raw exhaust gas  $u$  and component densities. Alternatively, Equation A.5-12 may be used to calculate  $u$  values.

**Table A.11.1.**

**Raw exhaust gas  $u$  and component densities (for emission concentration expressed in ppm) for engines operated solely on hydrogen**

<i>Fuel</i>	$\rho_e$	<i>Gas</i>					
		<i>NO<sub>x</sub></i>	<i>CO</i>	<i>HC</i>	<i>CO<sub>2</sub></i>	<i>O<sub>2</sub></i>	<i>CH<sub>4</sub></i>
		$\rho_{gas} [kg/m^3]$					
		2.053	1.250	<sup>a</sup>	1.9636	1.4277	0.716
		$u_{gas}^b$					
<b>Hydrogen</b>	<b>1.1872</b>	<b>0.001729</b>	<b>0.001053</b>	<b>0.000075</b>	<b>0.001654</b>	<b>0.001203</b>	<b>0.000603</b>

<sup>a</sup> depending on fuel

<sup>b</sup> at  $\lambda = 2$ , dry air, 273 K, 101.3 kPa

### 8.4. Mass flow rate of the exhaust gas

8.4.1. Equation A.5-15 or A.5-17 shall be used to calculate the mass flow rate of the exhaust gas.

8.4.2. Where Equation A.5-17 is used to calculate the mass flow rate of the exhaust, then Equation A.5-18 shall not be used to calculate  $A/F_{st}$ , and instead a value of 34.2282 shall be used.

Equation A.5-19 shall not be used to calculate excess air ratio ( $\lambda_i$ ) and instead  $\lambda_i$  shall be measured by a lambda sensor according to Annex 4 paragraph 9.4.10..

### 8.5. Cycle specific CO<sub>2</sub> emissions

Calculation of cycle specific CO<sub>2</sub> using equation A.5-63 is not required.

### 9. Carbon Flow Check

The carbon flow check set out in Annex 5 appendix A.5 shall not be required. The carbon flow check may be performed on a diesel fuelled engine prior to the installation of the engine operated solely on hydrogen.