19 March 2025

Agreement

Concerning the Adoption of Harmonized Technical United Nations Regulations for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these United Nations Regulations*

(Revision 3, including the amendments which entered into force on 14 September 2017)

Addendum 48 – UN Regulation No. 49

Revision 5 – Amendment 9

Supplement 12 to the 05 series of amendments – Date of entry into force: 10 January 2025

Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines and positive ignition engines for use in vehicles

This document is meant purely as documentation tool. The authentic and legal binding text is: ECE/TRANS/WP.29/2024/45.

UNITED NATIONS

* Former titles of the Agreement:
Agreement concerning the Adoption of Uniform Conditions of Approval and Reciprocal Recognition of Approval for Motor Vehicle Equipment and Parts, done at Geneva on 20 March 1958 (original version);
Agreement concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions, done at Geneva on 5 October 1995 (Revision 2).

Paragraph 2.2.2., amend to read:

"2.2.2. Symbols for chemical component

CH_4	Methane
C_2H_6	Ethane
C_2H_5OH	Ethanol
C_3H_8	Propane
CO	Carbon Monoxide
DOP	Di-Octylphtalate
CO_2	Carbon Dioxide
H_2	Hydrogen
HC	Hydrocarbons
NMHC	Non-Methane Hydrocarbons
NO_x	Oxides of Nitrogen
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
O_2	Oxygen
PT	Particulates"

Paragraph 2.2.4., amend to read:

"2.2.4. Symbols for the fuel composition

w_{ALF}	Hydrogen content of fuel, per cent mass
w_{BET}	Carbon content of fuel, per cent mass
w_{GAM}	Sulphur content of fuel, per cent mass
w_{DEL}	Nitrogen content of fuel, per cent mass
w_{EPS}	Oxygen content of fuel, per cent mass
α	Molar hydrogen ratio
β	Molar carbon ratio
γ	Molar sulphur ratio
δ	molar nitrogen ratio
ε	Molar oxygen ratio

referring to a fuel $C_\beta H_\alpha O_\varepsilon N_\delta S_\gamma$

$\beta = 1$ for carbon based fuels, $\beta = 0$ for hydrogen fuel"

Paragraph 2.2.4., amend to read:

"2.2.5. Standards referenced by this Regulation

ISO 15031-1	ISO 15031-1: 2001 Road vehicles - Communication between vehicle and external equipment for emissions related diagnostics - Part 1: General information.
ISO 15031-2	ISO/PRF TR 15031-2: 2004 Road vehicles - Communication between vehicle and external equipment for emissions related diagnostics - Part 2: Terms, definitions, abbreviations and acronyms.

ISO 15031-3	ISO 15031-3: 2004 Road vehicles - Communication between vehicle and external equipment for emissions related diagnostics - Part 3: Diagnostic connector and related electrical circuits, specification and use.
SAE J1939-13	SAE J1939-13: Off-Board Diagnostic Connector.
ISO 15031-4	ISO DIS 15031-4.3: 2004 Road vehicles - Communication between vehicle and external equipment for emissions related diagnostics - Part 4: External test equipment.
SAE J1939-73	SAE J1939-73: Application Layer – Diagnostics.
ISO 15031-5	ISO DIS 15031-5.4: 2004 Road vehicles - Communication between vehicle and external equipment for emissions related diagnostics - Part 5: Emissions-related diagnostic services.
ISO 15031-6	ISO DIS 15031-6.4: 2004 Road vehicles - Communication between vehicle and external equipment for emissions related diagnostics - Part 6: Diagnostic trouble code definitions.
SAE J2012	SAE J2012: Diagnostic Trouble Code Definitions Equivalent to ISO/DIS 15031-6, April 30, 2002.
ISO 15031-7	ISO 15031-7: 2001 Road vehicles - Communication between vehicle and external equipment for emissions related diagnostics - Part 7: Data link security.
SAE J2186	SAE J2186: E/E Data Link Security, dated October 1996.
ISO 15765-4	ISO 15765-4: 2001 Road vehicles - Diagnostics on Controller Area Network (CAN) - Part 4: Requirements for emissions-related systems.
SAE J1939	SAE J1939: Recommended Practice for a Serial Control and Communications Vehicle Network.
ISO 16185	ISO 16185: 2000 Road vehicles – engine family for homologation.
ISO 2575	ISO 2575: 2000 Road vehicles – Symbols for controls, indicators and tell-tales.
ISO 16183	ISO 16183: 2002 Heavy duty engines - Measurement of gaseous emissions from raw exhaust gas and of particulate emissions using partial flow dilution systems under transient test conditions.
ISO 14687	ISO 14687-2019 Hydrogen fuel quality – Product specification."

Insert a new paragraph 3.5., to read:

"3.5. Application for type approval of engines fuelled with hydrogen

3.5.1. In case of an application for type approval of engines fuelled with hydrogen, hydrogen shall be the fuel the engine is designed to run on primarily.

Requirements for dual-fuel hydrogen engines have not yet been established under this regulation."

Paragraph 4.1.1., amend to read:

"4.1.1. In the case of diesel, ethanol, LNG20, or Hydrogen fuel the parent engine meets the requirements of this Regulation on the reference fuel specified in Annex 5."

Insert a new paragraph 4.6.3.3., to read:

"4.6.3.3. For hydrogen fuelled engines the approval mark shall contain a letter(s) after the national symbol, the purpose of which is to distinguish the fuel type and the working principal for which the approval has been granted. This letter(s) will be as follows:

(a) T in case of a PI engine being approved and calibrated for gaseous hydrogen

(b) TD in case of a CI engine being approved and calibrated for gaseous hydrogen

(c) U in case of a PI engine being approved and calibrated for liquefied hydrogen

(d) UD in case of a CI engine being approved and calibrated for liquefied hydrogen"

Insert a new paragraph 5.1.10., to read:

"5.1.10. Provisions for engines fuelled with hydrogen

5.1.10.1. In case of an application for type approval of engines fuelled with hydrogen, the emission measurement system shall comply with 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 position."

Paragraph 5.2.1., amend to read:

"5.2.1. Limit values

The specific mass of the carbon monoxide, of the total hydrocarbons, of the oxides of nitrogen and of the particulates, as determined on the ESC test, and of the smoke opacity, as determined on the ELR test, shall not exceed the amounts shown in Table 1.

The specific mass of the carbon monoxide, of the non-methane hydrocarbons, of the methane, of the oxides of nitrogen and of the particulates as determined on the ETC test shall not exceed the amounts shown in Table 2.

Table 1
Limit values — ESC and ELR tests

Row	*Mass of carbon monoxide (CO) g/kWh*	*Mass of hydrocarbons (HC) g/kWh*	*Mass of nitrogen oxides (NO_x) g/kWh*	*Mass of particulates (PT) g/kWh*	*Smoke[b] m^{-1}*
A (2000)	2.1	0.66	5.0	0.10 // 0.13[a]	0.8
B1 (2005)	1.5	0.46	3.5	0.02	0.5
B2 (2008)	1.5	0.46	2.0	0.02	0.5
C (Enhanced Environmentally Friendly Vehicle (EEV))	1.5	0.25	2.0	0.02	0.15

[a] For engines having a swept volume of less than 0.75 dm³ per cylinder and a rated power speed of more than 3,000 min^{-1}

[b] Not applicable for engines fuelled with hydrogen show in paragraph 4.6.3.3.

Table 2
Limit values — ETC test

Row	*Mass of carbon monoxide (CO) g/kWh*	*Mass of non-methane hydrocarbons (NMHC) g/kWh*	*Mass of (CH4)[a] g/kWh*	*Mass of nitrogen oxides (NO_x) g/kWh*	*Mass of particulates (PT) (PT)[b] g/kWh*
A (2000)	5.45	0.78	1.6	5.0	0.16 // 0.21[c]
B1 (2005)	4.0	0.55	1.1	3.5	0.03
B2 (2008)	4.0	0.55	1.1	2.0	0.03
C (EEV)	3.0	0.40	0.65	2.0	0.02

[a] For NG engines only.

[b] Not applicable for gas fuelled engines at stages B1 and B2.

[c] For engines having a swept volume of less than 0.75 dm³ per cylinder and a rated power speed of more than 3,000 min^{-1}

[d] For engines where all the fuels used have a molar carbon to hydrogen ratio of 0 as defined in paragraph 8. of Annex 4A, the measurement of CH_4 is not required and the manufacturer, technical service or Type Approval Authority may choose to measure the total hydrocarbon (THC) emissions instead of measuring the non-methane hydrocarbon emissions. In that case, the emission limit for the total hydrocarbon emissions is the same as shown in paragraph 5.2. of this Regulation for non-methane hydrocarbon emissions."

Paragraph 7.2.1., amend to read:

"7.2.1. CI engines"

Paragraph 7.2.2., amend to read:

"7.2.2. PI engines"

Insert a new paragraph 8.3.2.6., to read

"*8.3.2.6.* For hydrogen fuelled engines, all these tests may be conducted with the applicable market fuels. However, at the manufacturer's request, the reference fuels described in Annex 5 to this Regulation may be used."

Paragraph 8.3.2.6., amend to read:

"8.3.2.7. Tests for conformity of production of a gas fuelled engine laid out for operation on one specific fuel composition shall be performed on the fuel for which the engine has been calibrated."

Annex 1, amend to read:

"Annex 1. Information document

This information document is related to the approval according to Regulation No. 49. It is referring to measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines include fuelled with hydrogen(TD/UD) for use in vehicles, and the emission of gaseous pollutants from positive-ignition engines fuelled with natural gas liquefied petroleum gas hydrogen(T/U) for use in vehicles.

Vehicle type/parent engine/engine type[1]

0. General
0.1. Make (name of undertaking):
0.2. Type and commercial description (mention any variants):
0.3. Means and location of identification of type, if marked on the vehicle:
0.4. Category of vehicle (if applicable):
0.5. Category of engine: diesel/NG fuelled/LPG fuelled/ethanol fuelled

/hydrogen fuelled[1]
0.6. Name and address of manufacturer:
0.7. Location of statutory plates and inscriptions and method of affixing:
0.8. In the case of components and separate technical units, location and method of affixing of the ECE approval mark:
0.9. Address(es) of assembly plant(s):"

Annex 1- Appendix1, paragraph 1.14., amend to read:

"1.14. Fuel: Diesel/LPG/NG-H/NG-L/NG-HL/ethanol /LNG /LNG_{20} /Hydrogen (T) /Hydrogen (TD) /Hydrogen (U) /Hydrogen (UD)[2,5]"

Annex 1- Appendix1, paragraph 3.1., amend to read:

"3.1. Compression-ignition (C.I.) engines, including dual-fuel engines"

Annex 1- Appendix1, paragraph 3.2., amend to read:

"3.2. Positive-ignition (P.I.) engines, including dual-fuel engines"

Annex 1- Appendix1, paragraph 9.3., amend to read:

"9.3. Compression-ignition (C.I.) / positive-ignition (P.I.) engines"

Annex 1- Appendix2, paragraph 2.1., amend to read:

"2.1. Name of compression-ignition (C.I.) engine family:"

Annex 1- Appendix2, paragraph 2.2., amend to read:

"2.2. Name of positive-ignition (P.I.) engine family:"

Annex 1- Appendix3, paragraph 1.14., amend to read:

"1.14. Fuel: Diesel/LPG/NG-H/NG-L/NG-HL/ethanol/LNG/LNG_{20} /Hydrogen (T) /Hydrogen (TD) /Hydrogen (U) /Hydrogen (UD)[2,5]"

Annex 1- Appendix3, paragraph 3.1., amend to read:

"3.1. Compression-ignition (C.I.) engines, including dual-fuel engines"

Annex 1- Appendix3, paragraph 3.2., amend to read:

"3.2. Positive-ignition (P.I.) engines, including dual-fuel engines"

Annex 1- Appendix1, paragraph 6.3.1., amend to read:

"6.3.1. Compression-ignition (C.I.) / positive-ignition (P.I.) engines;[4]"

Annex 2A, amend to read:

"…of a compression-ignition (C.I.) engine type or family (Diesel or Ethanol or Hydrogen (TD) or Hydrogen (UD)), or a positive-ignition (P.I.) engine type or family (NG or LPG or Hydrogen (T) or Hydrogen (U)),[2] as a separate technical unit with regard to the emission of pollutants pursuant to Regulation No. 49, 05 series of amendments"

Annex 2A, paragraph 11.4., amend to read:

"

ETC test					
DF:	*CO*	*NMHC*	*CH_4*	*NO_x*	*PT*
Emissions	*CO (g/kWh)*	*NMHC (g/kWh)[2,4]*	*CH_4 (g/kWh)[2,4]*	*NO_x (g/kWh)*	*PT (g/kWh)[2]*
Measured with regeneration:					
Measured without regeneration:					

Measured/weighted:					
Calculated with DF:					

"

Annex 2A, foot note, amend to read:

"[1] Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

[2] Strike out what does not apply.

[3] For each member of the family.

[4] For engines where all the fuels used have a molar carbon to hydrogen ratio of 0 as defined in paragraph 8. of Annex 4A, the measurement of CH4 is not required and the manufacturer, technical service or Type Approval Authority may choose to measure the total hydrocarbon (THC) emissions instead of measuring the non-methane hydrocarbon emissions. In that case, the emission limit for the total hydrocarbon emissions is the same as shown in paragraph 5.2. of this Regulation for non-methane hydrocarbon emissions. "

Annex 2B, paragraph 9.4., amend to read:

"

ETC test					
DF:	*CO*	*NMHC*	*CH_4*	*NO_x*	*PT*
Emissions	*CO (g/kWh)*	*NMHC (g/kWh)[2,4]*	*CH4 (g/kWh)[2,4]*	*NO_x (g/kWh)*	*PT (g/kWh)[2]*
Measured with regeneration:					
Measured without regeneration:					
Measured/weighted:					
Calculated with DF:					

"

Annex 2B, foot note, amend to read:

"[1] Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

[2] Strike out what does not apply.

[3] For engines where all the fuels used have a molar carbon to hydrogen ratio of 0 as defined in paragraph 8. of Annex 4A, the measurement of CH4 is not required and the manufacturer, technical service or Type Approval Authority may choose to measure the total hydrocarbon (THC) emissions instead of measuring the non-methane hydrocarbon emissions. In that case, the emission limit for the total hydrocarbon emissions is the same as shown in paragraph 5.2. of this Regulation for non-methane hydrocarbon emissions."

Annex 4A, Appendix 1, paragraph 5., amend to read:

"5. Calculation of the gaseous emissions

Calculation of hydrocarbons and/or non-methane hydrocarbons is based on the following molar carbon/hydrogen/oxygen ratios (C/H/O) of the fuel:

CH1.85 for diesel,

CH3O0.5 for ethanol for dedicated C.I. engines,

CH2.525 for LPG (liquefied petroleum gas),

CH2.93 for NG (Non-Methane Hydrocarbons (NMHC)).

CH4 for NG

H2 for hydrogen."

Annex 4A, Appendix 1, paragraph 5.2., amend to read:

"5.2. Dry / wet correction

The measured concentration shall be converted to a wet basis according to the following formulae, if not already measured on a wet basis. The conversion shall be done for each individual mode.

The u_{gas}-values and molar ratios as described in paragraphs A.5.2. and A.5.3. of Appendix 5 to Annex 11 shall be used for dual-fuel engines, operating in dual-fuel mode,

$$c_{wet} = k_W \times c_{dry}$$

For the raw exhaust gas:

(a)

$$k_{W,r} = \left(1 - \frac{1.2442 \times H_a + 111.19 \times w_{ALF} \times \frac{q_{mf}}{q_{mad}}}{773.4 + 1.2442 \times H_a + \frac{q_{mf}}{q_{mad}} \times k_f \times 1000}\right) \times 1.008$$

or:

(b)

$$k_{W,r} = \left(1 - \frac{1.2442 \times H_a + 111.19 \times w_{ALF} \times \frac{q_{mf}}{q_{mad}}}{773.4 + 1.2442 \times H_a + \frac{q_{mf}}{q_{mad}} \times k_f \times 1000}\right) \Big/ \left(1 - \frac{p_r}{p_b}\right)$$

or:

(c)

$$k_{w,a} = \left(\frac{1}{1 + \alpha \times 0.005 \times (c_{CO2} + c_{CO})} - k_{w1}\right) \times 1.008$$

with

k_f = 0.055594 x w_{ALF} + 0.0080021 x w_{DEL} + 0.0070046 x w_{EPS}

and

$$k_{w1} = \frac{1.608 \times H_a}{1{,}000 + (1.608 \times H_a)}$$

Where:

H_a = intake air humidity, g water per kg dry air

w_{ALF} = hydrogen content of the fuel, per cent mass

$q_{mf,i}$ = instantaneous fuel mass flow rate, kg/s

$q_{mad,i}$ = instantaneous dry intake air mass flow rate, kg/s

p_r = water vapour pressure after cooling bath, kPa

p_b = total atmospheric pressure, kPa

w_{DEL} = nitrogen content of the fuel, per cent mass

w_{EPS} = oxygen content of the fuel, per cent mass

α = molar hydrogen ratio of the fuel

c_{CO2} = dry CO_2 concentration, per cent

c_{CO} = dry CO concentration, per cent

(a) and (b) are principally identical with the factor 1.008 in (a) and (c) being an approximation for the more accurate denominator in (b). (c) is not applicable, if one of the fuels used has a molar carbon to hydrogen ratio of 0. (a) to (c) are not applicable in the case that water injection is used.

For the diluted exhaust gas:

(d)

$$K_{We1} = \left(1 - \frac{\alpha \times \% c_{wCO2}}{200}\right) - K_{W1}$$

or:

(e)

$$K_{We2} = \left(\frac{\left(1 - K_{W1}\right)}{1 + \frac{\alpha \times \% c_{dCO2}}{200}}\right)$$

(d) and (e) are not applicable if one of the fuels used has a molar carbon to hydrogen ratio of 0.

…"

Annex 4A, Appendix 1, paragraph 5.5., Table 6, amend to read:

"Table 6
Values of u_{gas} in the raw and dilute exhaust gas for various exhaust components

Fuel		*NO_x*	*CO*	*THC/NMHC*	*CO_2*	*CH_4*	*Density*
Diesel	Exhaust raw	0.001587	0.000966	0.000479	0.001518	0.000553	1.2943
	Exhaust dilute	0.001588	0.000967	0.000480	0.001519	0.000553	1.293
Ethanol	Exhaust raw	0.001609	0.000980	0.000805	0.001539	0.000561	1.2757
	Exhaust dilute	0.001588	0.000967	0.000795	0.001519	0.000553	1.293
CNG	Exhaust raw	0.001622	0.000987	0.000523	0.001552	0.000565	1.2661
	Exhaust dilute	0.001588	0.000967	0.000584	0.001519	0.000553	1.293
Propane	Exhaust raw	0.001603	0.000976	0.000511	0.001533	0.000559	1.2805
	Exhaust dilute	0.001588	0.000967	0.000507	0.001519	0.000553	1.293
Butane	Exhaust raw	0.001600	0.000974	0.000505	0.001530	0.000558	1.2832
	Exhaust dilute	0.001588	0.000967	0.000501	0.001519	0.000553	1.293
Hydrogen	Exhaust raw	0.001729	0.001053	0.000075	0.001654	0.000603	1.1872

Notes:

- u values of raw exhaust based on ideal gas properties at λ = 2. dry air, 273 K, 101.3 kPa
- u values of dilute exhaust based on ideal gas properties and density of air

- u values of CNG accurate within 0.2 per cent for mass composition of: C = 66 to 76 per cent; H = 22 to 25 per cent; N = 0 to 12 per cent
- u value of CNG for HC corresponds to $CH_{2.93}$ (for total HC use u value of CH_4)

…"

Annex 4A, Appendix 2, paragraph 3., amend to read:

"3. Emissions test run

At the manufacturers request, a dummy test may be run for conditioning of the engine and exhaust system before the measurement cycle.

NG and LPG and hydrogen fuelled engines shall be run-in using the ETC test. The engine shall be run over a minimum of two ETC cycles and until the CO emission measured over one ETC cycle does not exceed by more than 10 per cent the CO emission measured over the previous ETC cycle."

Annex 4A, Appendix 2, paragraph 4.2.5., amend to read:

"4.2.5. 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 calculation of the instantaneous exhaust gas mass flow is as follows:

$$q_{mew,i} = q_{maw,i} \times \left(1 + \frac{1}{A/F_{st} \times \lambda_i}\right)$$

With:

$$A/F_{st} = \frac{138{,}0 \times (\beta + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma)}{12{,}011 \times \beta + 1{,}00794 \times \alpha + 15{,}9994 \times \varepsilon + 14{,}0067 \times \delta + 32{,}065 \times \gamma}$$

$$\lambda_i = \frac{\beta \times \left(100 - \frac{c_{COd} \times 10^{-4}}{2} - c_{HCw} \times 10^{-4}\right) + \left(\frac{\alpha}{4} \times \frac{1 - \frac{2 \times c_{COd} \times 10^{-4}}{3{,}5 \times c_{CO2d}}}{1 + \frac{c_{CO} \times 10^{-4}}{3{,}5 \times c_{CO2d}}} - \frac{\varepsilon}{2} - \frac{\delta}{2}\right) \times (c_{CO2d} + c_{COd} \times 10^{-4})}{4{,}764 \times \left(\beta + \frac{\alpha}{4} - \frac{\varepsilon}{2} + \gamma\right) \times (c_{CO2d} + c_{COd} \times 10^{-4} + c_{HCw} \times 10^{-4})}$$

Where:

A/F_{st} = stoichiometric air to fuel ratio, kg/kg

β is the molar carbon ratio of the fuel, with β=1 for fuels containing carbon and β=0 for fuels with a molar carbon to hydrogen ratio of 0 as defined in paragraph 4. of this annex.

λ = excess air ratio calculated by λ_i or measured by a lambda sensor

c_{CO2} = dry CO_2 concentration, per cent

c_{CO} = dry CO concentration, ppm

c_{HC} = HC concentration, ppm

λ_i is not applicable if one of the fuels used has a molar carbon to hydrogen ratio of 0 as defined in paragraph 4. of this annex."

The air flowmeter shall meet the accuracy specifications of paragraph 2.2. of Appendix 4 to this annex, the CO_2 analyzer used shall meet the specifications of paragraph 3.3.2. of Appendix 4 to this annex and the total system shall meet the accuracy specifications for the exhaust gas flow.

Optionally, air to fuel ratio measurement equipment such as a zirconia type sensor may be used for the measurement of the excess air ratio which meets the specifications of paragraph 3.3.6. of Appendix 4 to this annex."

Annex 4A, Appendix 5, paragraph 1.9.1., amend to read:

"1.9.1. CO analyzer interference check

Water and CO_2 can interfere with the CO analyzer performance. Therefore, a CO_2 span gas having a concentration of 80 to 100 per cent of full scale of the maximum operating range used during testing shall be bubbled through water at room temperature and the analyzer response recorded. The analyzer response shall not be more than 2 per cent of the mean CO concentration expected during testing or 20 ppm, whichever is larger."

Annex 4A, Appendix 5, paragraph 3.2.2., amend to read:

"3.2.2. Carbon flow check

(a) A carbon flow check using actual exhaust is recommended for detecting measurement and control problems and verifying the proper operation of the partial flow system. The carbon flow check should be run at least each time a new engine is installed, or something significant is changed in the test cell configuration.

(b) The engine shall be operated at peak torque load and speed or any other steady state mode that produces 5 per cent or more of CO_2. The partial flow sampling system shall be operated with a dilution factor of about 15 to 1.

(c) If a carbon flow check is conducted, the procedure given in Appendix 6 to this annex shall be applied. The carbon flow rates shall be calculated according to paragraphs 2.1. to 2.3. of Appendix 6 to this annex. All carbon flow rates should agree to within 6 per cent of each other. In the case that a hydrogen fuelled engine is to be tested, the carbon flow check should be performed on a diesel fuelled engine prior to the installation of the hydrogen fuelled engine."

Annex 4A, Appendix 6, paragraph 2.4., amend to read:

"2.4. The molecular mass (M_{re}) of the exhaust gas shall be calculated as follows:

$$M_{re} = \frac{1+\frac{q_{mf}}{q_{maw}}}{\frac{q_{mf}}{q_{maw}} \times \frac{\frac{\alpha}{4}+\frac{\varepsilon}{2}+\frac{\delta}{2}}{12.01\times\beta+1.0079\times\alpha+15.999\times\varepsilon+14.006\times\delta+32.06\times\gamma} + \frac{\frac{H_a\times10^{-3}}{2\times1.0079+15.999}+\frac{1}{M_{ra}}}{1+H_a\times10^{-3}}}$$

Where:

q_{mf} = fuel mass flow rate, kg/s

q_{maw} = intake air mass flow rate on wet basis, kg/s

H_a = humidity of intake air, g water per kg dry air

M_{ra} = molecular mass of dry intake air (= 28.9 g/mol)

α, δ, ε, γ = molar ratios referring to a fuel $C_\beta H_\alpha O_\delta N_\varepsilon S_\gamma$.

Alternatively, the following molecular masses may be used:

M_{re} (diesel) = 28.9 g/mol

M_{re} (LPG) = 28.6 g/mol

M_{re} (NG) = 28.3 g/mol."

Annex 5, insert new paragraph 4., to read:

"4. Technical data of the Hydrogen reference fuels for testing compression-ignition or positive ignition

Characteristics	*Units*	*Limits*		*Test Method*
		Minimum	*Maximum*	
Hydrogen fuel index	% mole fraction	99.97		(a)
Total non-hydrogen gases	µmol/mol		300	
Lists of non-hydrogen gases and the specification of each contaminant (f)				
Water (H_2O)	µmol/mol		5	(e)
Total hydrocarbons(b) except methane (C1 equivalent)	µmol/mol		2	(e)
Methane (CH_4)	µmol/mol		100	(e)
Oxygen (O_2)	µmol/mol		5	(e)
Helium (He)	µmol/mol		300	(e)
Total Nitrogen (N_2) and Argon (Ar) (b)	µmol/mol		300	(e)
Carbon dioxide (CO_2)	µmol/mol		2	(e)
Carbon monoxide (CO) (c)	µmol/mol		0.2	(e)
Total sulfur compounds (d) (H_2S basis)	µmol/mol		0.004	(e)
Formaldehyde (HCHO)	µmol/mol		0.2	(e)
Formic acid (HCOOH)	µmol/mol		0.2	(e)
Ammonia (NH_3)	µmol/mol		0.1	(e)
Total halogenated compounds (e) (Halogenate ion basis)	µmol/mol		0.05	(e)

(a) 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.

(b) Total hydrocarbons except methane include oxygenated organic species.

(c) The sum of measured CO, HCHO and HCOOH shall not exceed 0.2 µmol/mol

(d) As a minimum, total sulphur compounds include H2S, COS, CS2 and mercaptans, which are typically found in natural gas.

(e) Test method shall be documented. Test methods defined in ISO21087 are preferable.

(f) The analysis of specific contaminants depending on the production process shall be exempted. A vehicle manufacturer shall provide the responsible authority reasons for exempting specific contaminants."

Annex 9A, paragraph 3.2.1., amend to read:

"3.2.1. Introduction

From the dates given in paragraph 5.4.2. of this Regulation, the OBD system of all Compression Ignition (hereinafter, this is called "CI") engines and of vehicles equipped with a CI engine shall indicate the failure of an emission-related component or system when that failure results in an increase in emissions above the appropriate OBD thresholds given in the table in paragraph 5.4.4. of this Regulation."

Annex 9A, paragraph 3.2.3.1., amend to read:

"3.2.3.1. As an alternative to monitoring against the appropriate OBD threshold limits with respect to paragraphs 3.2.2.1. to 3.2.2.4. of this annex, OBD systems of CI engines may in accordance with paragraph 5.4.1.1. of this Regulation monitor for major functional failure of the following components:

…"

Annex 9A, paragraph 3.3.1., amend to read:

"3.3.1. From the dates given in paragraph 5.4.2. of this Regulation the OBD system of all CI or Positive Ignition (hereinafter, this is called "PI") engines and of vehicles equipped with a CI or a PI engine shall indicate the failure of an emission-related component or system of the engine system when that failure results in an increase in emissions above the appropriate OBD thresholds given in the table in paragraph 5.4.4. of this Regulation.

…"

Annex 9B, paragraph 3.36., amend to read:

"3.36. Abbreviations

AES	Auxiliary Emission Strategy
CI	Compression Ignition
CV	Crankcase Ventilation
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter or Particulate Trap including catalyzed DPFs, Continuously Regenerating Traps (CRT) and other soot particle filters
DTC	Diagnostic trouble code
EGR	Exhaust Gas Recirculation
HC	Hydrocarbon
LNT	Lean NOx Trap (or NOx absorber)
LPG	Liquefied Petroleum Gas
MECS	Malfunction Emission Control Strategy
NG	Natural Gas
NOx	Oxides of Nitrogen
OTL	OBD Threshold Limit
PI	Positive Ignition
PM	Particulate Matter
SCR	Selective Catalytic Reduction
SW	Screen Wipers
TFF	Total Functional Failure monitoring
VGT	Variable Geometry Turbocharger
VVT	Variable Valve Timing"

Annex 9B, paragraph 5.2.3., amend to read:

"5.2.3. Low fuel level

Manufacturers may request approval to disable monitoring systems that are affected by low fuel level / pressure or running out of fuel (e.g. diagnosis of a malfunction of the fuelling system or misfiring) as follows:

	Liquid fuel storage	Gaseous fuel storage
a) The low fuel level considered for such a disablement shall not exceed 100 litres or 20 per cent of the nominal capacity of the fuel tank, whichever is lower.	X	
b) The low fuel pressure in the tank considered for such a disablement shall not exceed 20 per cent of the usable range of fuel tank pressure.		X

"

Annex 9B, Appendix 3 – Item 6, amend to read:

"Appendix 3 - Item 6

Exhaust Gas Recirculation (EGR) system monitoring

The OBD system shall monitor the following elements of the EGR system on engines so equipped for proper operation:

	CI engine	PI engine
(a1) EGR low/high flow: the EGR system's ability to maintain the commanded EGR flow rate, detecting both “flow rate too low” and “flow rate too high” conditions – emission threshold monitoring.	X	
(a2) EGR low/high flow: the EGR system's ability to maintain the commanded EGR flow rate, detecting both “flow rate too low” and “flow rate too high” conditions – performance monitoring (monitoring requirement to be further discussed).		X
(b) Slow response of the EGR actuator: the EGR system's ability to achieve the commanded flow rate within a manufacturer specified time interval following the command – performance monitoring.	X	X

(c) EGR cooler under cooling performance: the EGR cooler system's ability to achieve the manufacturer's specified cooling performance – performance monitoring.	X	X

…"

Annex 9B, Appendix 3 – Item 7, amend to read:

"Appendix 3 - Item 7

Fuel System monitoring

The OBD system shall monitor the following elements of the fuel system on engines so-equipped for proper operation:

	CI engine	PI engine
(a) Fuel system pressure control: fuel system ability to achieve the commanded fuel pressure in closed loop control – performance monitoring.	X	
(b) Fuel system pressure control: fuel system ability to achieve the commanded fuel pressure in closed loop control in the case where the system is so constructed that the pressure can be controlled independently of other parameters – performance monitoring.	X	
(c) Fuel injection timing: fuel system ability to achieve the commanded fuel timing for at least one of the injection events when the engine is equipped with the appropriate sensors – performance monitoring.	X	
(d) Fuel injection system: ability to maintain the desired air-fuel ratio (incl. but not limited to self adaptation features) – performance monitoring.		X

"

Annex 9B, Appendix 3 – Item 8, amend to read:

"Appendix 3 - Item 8

Air handling and turbocharger/Boost pressure control system

The OBD system shall monitor the following elements of the Air handling and Turbocharger/Boost pressure Control System on engines so-equipped for proper operation:

	CI engine	PI engine
(a1) Turbo under/over boost: turbo boost system's ability to maintain the commanded boost pressure, detecting both "boost pressure too low" and "boost pressure too high" conditions – emission threshold monitoring.	X	
(a2) Turbo under/over boost: turbo boost system's ability to maintain the commanded boost pressure, detecting both "boost pressure too low" and "boost pressure too high" conditions – performance monitoring (monitoring requirement to be further discussed).		X
(b) Variable Geometry Turbo (VGT) slow response: VGT system's ability to achieve the commanded geometry within a manufacturer specified time-performance monitoring.	X	X
(c) Charge air cooling: Charge air cooling system efficiency - total functional failure.	X	X

…"

Annex 9B, Appendix 3 – Item 10, amend to read:

"Appendix 3 - Item 10

Misfire Monitoring

	CI engine	PI engine
(a) No prescriptions.	X	
(b) Misfire that may cause catalyst damage (e.g. by monitoring a certain percentage of misfiring in a certain period of time) – performance monitoring (monitoring requirement to be further discussed together with items 6 and 8).		X

"

Annex 9B, Appendix 3 – Item 13, amend to read:

"Appendix 3 - Item 13

Exhaust gas and oxygen sensors monitoring

The OBD system shall monitor:

	CI engine	PI engine
(a) The electrical elements of the exhaust gas sensors on engines so-equipped for proper operation according to item 1 to this appendix – component monitoring.	X	X
(b) Both the primary and secondary (fuel control) oxygen sensors. These sensors are considered as exhaust gas sensors to be monitored for proper operation according to item 1 to this appendix – component monitoring.		X

"

Annex 9B, Appendix 3 – Item 15, amend to read:

"Appendix 3 - Item 15

Three-way catalyst

The OBD system shall monitor the three-way catalyst on engines so-equipped for proper operation:

	CI engine	PI engine
(a) Three-way Catalyst Conversion efficiency: the catalyst ability to convert NOx and CO – performance monitoring		X

"