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Subject: **COMMISSION REGULATION (EU) No .../.. of XXX** amending Regulation (EC) No 692/2008, as regards type-approval requirements for motor vehicles fuelled by hydrogen and mixtures of hydrogen and natural gas with respect to emissions, and the inclusion of specific information regarding vehicles fitted with an electric power train in the information document for the purpose of EC type-approval

Delegations will find attached Commission document D016995/01.

Encl.: D016995/01



EUROPEAN COMMISSION

Brussels, XXX
D016995/01
[...] (2011) XXX draft

COMMISSION REGULATION (EU) No .../..

of XXX

amending Regulation (EC) No 692/2008, as regards type-approval requirements for motor vehicles fuelled by hydrogen and mixtures of hydrogen and natural gas with respect to emissions, and the inclusion of specific information regarding vehicles fitted with an electric power train in the information document for the purpose of EC type-approval

(Text with EEA relevance)

COMMISSION REGULATION (EU) No .../..

of XXX

amending Regulation (EC) No 692/2008, as regards type-approval requirements for motor vehicles fuelled by hydrogen and mixtures of hydrogen and natural gas with respect to emissions, and the inclusion of specific information regarding vehicles fitted with an electric power train in the information document for the purpose of EC type-approval

(Text with EEA relevance)

THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Regulation (EC) No 715/2007 of the European Parliament and of the Council of 20 June 2007 on type approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information¹, and in particular article 5(3)(a)(f) and (i) thereof,

Whereas:

- (1) The Communication from the Commission to the European Parliament, the Council and the European Economic and Social Committee – A European strategy on clean and energy efficient vehicles², recognizes the existence of a wide range of technologies (electricity, hydrogen, biogas, and liquid biofuels) that are likely to contribute significantly to the Europe 2020 priorities of developing an economy based on knowledge and innovation (smart growth) and promoting a more resource efficient, greener and more competitive economy (sustainable growth).
- (2) The internal combustion engine (ICE) is likely to remain dominant in road vehicles in the short and medium term perspective; therefore, a smooth transition from ICE to other kinds of power-trains based on electricity (electric battery, fuel cell) could be facilitated by adapting ICE to clean fuels, such as hydrogen (H₂) or mixtures of hydrogen and natural gas (H₂NG).
- (3) Given the uncertainty surrounding the future of power-train technology and the likelihood that new technologies will represent an increasingly large share of the market, it is necessary to adapt current European type-approval legislation to those technologies.
- (4) Commission Regulation (EC) No 692/2008 of 18 July 2008 implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the

¹ OJ L 171, 29.6.2007, p. 1.

² COM(2010)186 final

Council on type-approval of motor vehicles with respect to emissions from light passenger and commercial vehicles (Euro 5 and Euro 6) and on access to vehicle repair and maintenance information³ does not currently include H2 and H2NG among the type of fuels considered. Therefore, it is appropriate to extend the type-approval procedure established in that Regulation to cover those fuels.

- (5) Regulation (EC) No 79/2009 of the European Parliament and of the Council of 14 January 2009 on type-approval of hydrogen-powered motor vehicles, and amending Directive 2007/46/EC⁴ established safety requirements for the type-approval of motor vehicles with regard to hydrogen propulsion. Environmental protection must also be achieved as nitrogen oxide emissions from hydrogen used as a fuel in ICEs may have an impact on the environment.
- (6) H2NG mixtures release into the atmosphere a certain amount of pollutants, mainly hydrocarbons, carbon monoxides, nitrogen oxides and particulate matters; these emissions have to be addressed.
- (7) The different formulae and parameters used for the determination of the results of the emission tests should be adapted for the specific cases of H2 and H2NG used in ICEs, as those formulae and parameters are strongly dependent on the type and characteristics of the fuel used.
- (8) The documents provided by the manufacturer to the national approval authorities should be updated in order to incorporate the relevant information concerning H2, H2NG and electric vehicles.
- (9) Regulation (EC) No 692/2008 should therefore be amended accordingly.
- (10) The measures provided for in this Regulation are in accordance with the opinion of the Technical Committee – Motor Vehicles,

HAS ADOPTED THIS REGULATION:

Article 1

Regulation (EC) No 692/2008 is hereby amended as follows:

1. Article 2 is amended as follows:

(a) Point 16 is replaced by the following:

"16. 'hybrid electric vehicle' (HEV) means a vehicle, including vehicles which draw energy from a consumable fuel only for the purpose of re-charging the electrical energy/power storage device, that, for the purpose of mechanical propulsion, draws energy from both of the following on-vehicle sources of stored energy/power:

(a) a consumable fuel;

³ OJ L 199, 28.7.2008, p. 1.

⁴ OJ L 35, 4.2.2009, p. 32.

(b) a battery, capacitor, flywheel/generator or other electrical energy/power storage device;"

(b) The following points are added:

"33. 'Electric power train' means a system consisting of one or more electric energy storage devices, one or more electric power conditioning devices and one or more electric machines that convert stored electric energy to mechanical energy delivered at the wheels for propulsion of the vehicle;

34. 'Pure electric vehicle' means a vehicle powered by an electric power train only;

35. 'flex fuel H2NG vehicle' means a flex fuel vehicle that can run on different mixtures of hydrogen and NG/biomethane;

36. 'Hydrogen fuel cell vehicle' means a vehicle powered by a fuel cell that converts chemical energy from hydrogen into electric energy, for propulsion of the vehicle"

2. The annexes are amended in accordance with the Annex to this Regulation.

Article 2

This Regulation shall enter into force on the twentieth day following that of its publication in the *Official Journal of the European Union*.

This Regulation shall be binding in its entirety and directly applicable in all Member States.

Done at Brussels,

*For the Commission,
On behalf of the President
[...]
Member of the Commission*

ANNEX

The Annexes to Regulation (EC) No 692/2008 are amended as follows:

1. Annex I is amended as follows

(a) Point 1.1 is replaced by the following:

"1.1. Additional requirements for mono fuel gas vehicles, bi-fuel gas vehicles and flex fuel H2NG vehicles

(b) Point 1.1.1.1 is replaced by the following:

"1.1.1.1. A family means a group of vehicle types fuelled by LPG, NG/biomethane, H2NG, identified by a parent vehicle.";

(c) Point 1.1.2 is replaced by the following:

"1.1.2. In case of vehicles fuelled by LPG, NG/biomethane, H2NG, EC type-approval is granted subject to the following requirements:";

(d) In point 1.1.2.1. the following paragraph is added:

"In the case of a flex fuel H2NG vehicle, the composition range may vary from 0% hydrogen to a maximum percentage of hydrogen within the mixture, which shall be specified by the manufacturer. The parent vehicle shall demonstrate its capability to adapt to any percentage, within the range specified by the manufacturer. It shall also demonstrate its capability to adapt to any NG/biomethane composition that may occur across the market, regardless of the percentage of hydrogen in the mixture.";

(e) Points 1.1.2.2, 1.1.2.3 and 1.1.2.4 are replaced by the following:

"1.1.2.2. In the case of vehicles fuelled by LPG, NG/biomethane, the parent vehicle shall be tested in the type 1 test on the two extreme gas reference fuels set out in Annex IX. In the case of NG/biomethane, if the transition from one gas fuel to the other gas fuel is, in practice, aided through the use of a switch, this switch shall not be used during type-approval.

In the case of flex fuel H2NG vehicles, the parent vehicle shall be tested in the type 1 test with the following fuel compositions:

- 100% H-gas.

- 100% L-gas.

- The mixture of H-gas and the maximum percentage of hydrogen specified by the manufacturer.

- The mixture of L-gas and the maximum percentage of hydrogen specified by the manufacturer.

1.1.2.3. The vehicle is considered to conform if, under the tests and reference fuels mentioned in point 1.1.2.2, the vehicle complies with the emission limits.

1.1.2.4. In the case of vehicles fuelled by LPG or NG/biomethane, the ratio of emission results 'r' shall be determined for each pollutant as follows:

Type of fuel	Reference fuels	Calculation of “r”
LPG	fuel A	$r = \frac{B}{A}$
	fuel B	
NG/Biomethane	fuel G20	$r = \frac{G\ 25}{G\ 20}$
	fuel G25	

”;

(f) The following point 1.1.2.5 is inserted:

”1.1.2.5. In the case of flex fuel H2NG vehicles, two ratios of emission results 'r₁' and 'r₂', shall be determined for each pollutant as follows:

Type of fuel	Reference fuels	Calculation of “r”
NG/biomethane	fuel G20	$r_1 = \frac{G25}{G20}$
	fuel G25	
H2NG	Mixture of hydrogen and G20 with the maximum percentage of hydrogen specified by the manufacturer	$r_2 = \frac{H2G25}{H2G20}$
	Mixture of hydrogen and G25 with the maximum percentage of hydrogen specified by the manufacturer	

”;

(g) In point 1.1.3, the first paragraph is replaced by the following:

“For the type-approval of a mono- fuel gas vehicle and bi-fuel gas vehicles operating in gas mode, fuelled by LPG or NG/biomethane, as a member of the family, a type 1 test shall be performed with one gas reference fuel. This reference fuel may be either of the gas reference fuels. The vehicle is considered to comply if the following requirements are met.”;

(h) The following point 1.1.4 is inserted:

"1.1.4. For the type-approval of a flex fuel H2NG vehicle as a member of a family, two type 1 tests shall be performed, the first test with 100% of either G20 or G25, and the second test with the mixture of hydrogen and the same NG/biomethane fuel used during the first test, with the maximum hydrogen percentage specified by the manufacturer.

The vehicle tested in accordance with the first paragraph shall be considered as complying if, in addition to requirements set out in points (a), (e) and (g) of point 1.1.3., the following requirements are met:

- (a) if the NG/biomethane fuel is the reference fuel G20, the emission result for each pollutant shall be multiplied by the relevant factors (r_1 for the first test and r_2 for the second test), calculated in section 1.1.2.5, if the relevant factor > 1 ; if the correspondent relevant factor < 1 , no correction is needed;
 - (b) if the NG/biomethane fuel is the reference fuel G25, the emission result for each pollutant shall be divided by the correspondent relevant factor (r_1 for the first test and r_2 for the second test) calculated in accordance with point 1.1.2.5, if the correspondent relevant factor < 1 ; if the correspondent relevant factor > 1 , no correction is needed;
 - (c) on the manufacturer's request the type 1 test must be performed with the four possible combinations of reference fuels, according to section 1.1.2.5, so that no correction is needed;
 - (d) if repeated tests are made on the same engine the results on reference fuel G20, or H2G20, and those on reference fuel G25, or H2G25 with the maximum hydrogen percentage specified by the manufacturer, shall first be averaged; the ' r_1 ' and ' r_2 ' factors shall then be calculated from these averaged results.";
- (i) Figure I.2.4 is replaced by the following:

"Figure I.2.4

Application of test requirements for type approval and extensions

Vehicle category	Vehicles with positive ignition engines including hybrids										Vehicles with compression engines including hybrids		Hydrogen Fuel cell vehicles		
	Mono fuel				Bi-fuel ⁽¹⁾		Flex-fuel ⁽¹⁾				Flex fuel	Mono-fuel		Pure electric vehicles	
	Petrol (E5)	LPG	NG/Biomethane	Hydrogen	Petrol (E5)	LPG	Petrol (E5)	Petrol (E5)	Ethanol (E85)	NG/Biomethane					Diesel (B5)
Reference fuel	Petrol (E5)	LPG	NG/Biomethane	Hydrogen	Petrol (E5)	LPG	Petrol (E5)	Petrol (E5)	Ethanol (E85)	NG/Biomethane	Diesel (B5)	Diesel (B5)			
Gaseous pollutants (Type 1 test)	Yes	Yes	Yes	Yes ⁽⁴⁾	Yes (both fuels)	Yes (both fuels)	Yes (both fuels)	Yes (both fuels)	Yes (both fuels)	Yes (both fuels)	Yes (B5 only) ⁽²⁾	Yes (B5 only) ⁽²⁾	----	----	----
Particulate mass and particulate number (Type 1 test)	Yes	-----	-----	----	Yes (petrol only)	Yes (petrol only)	Yes (petrol only)	Yes (petrol only)	Yes (both fuels)	----	Yes (B5 only) ⁽²⁾	Yes (B5 only) ⁽²⁾	----	----	----
Idle emissions (Type 2 test)	Yes	Yes	Yes	----	Yes (both fuels)	Yes (both fuels)	Yes (both fuels)	Yes (petrol only)	Yes (both fuels)	Yes (NG/biomethane only)	----	----	----	----	----
Crankcase emissions (Type 3 test)	Yes	Yes	Yes	----	Yes (petrol only)	Yes (petrol only)	Yes (petrol only)	Yes (petrol only)	Yes (petrol only)	Yes (NG/biomethane only)	----	----	----	----	----
Evaporative emissions (Type 4 test)	Yes	----	----	----	Yes (petrol)	Yes (petrol)	Yes (petrol only)	Yes (petrol)	Yes (petrol)	—	----	----	----	----	----

(4) Only NOx emissions shall be determined when the vehicle is running on hydrogen.;

(j) Point 4.9 is replaced by the following:

"4.9. Checking the conformity of a vehicle fuelled by LPG, natural gas or H2NG";

(k) Point 4.9.1 is replaced by the following:

"4.9.1. Tests for conformity of production may be performed with a commercial fuel of which the C3/C4 ratio lies between those of the reference fuels in the case of LPG, or of which the Wobbe index lies between those of the extreme reference fuels in the case of NG or H2NG. In that case a fuel analysis shall be presented to the approval authority.";

(l) Appendix 3 is amended as follows:

(i) Point 3.2.2 is replaced by the following:

"3.2.2. Fuel";

(ii) Point 3.2.2.1 is inserted:

"3.2.2.1. Light-duty vehicles: Diesel/Petrol/LPG/NG or Biomethane/Ethanol (E85) /Biodiesel /Hydrogen/H2NG (*)(**)"

*Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable)

**Vehicles can be fuelled with both petrol and a gaseous fuel but, where the petrol system is fitted for emergency purposes or starting only and of which the petrol tank cannot contain more than 15 litres of petrol, will be regarded for the test as vehicles which can only run on a gaseous fuel.";

(iii) The following points 3.2.18 to 3.2.19.4.3 are inserted:

3.2.18. Hydrogen fuelling system: yes/no (*)

3.2.18.1. EC type-approval number according to Regulation (EC) No 79/2009:
...

3.2.18.2. Electronic engine management control unit for hydrogen fuelling

3.2.18.2.1. Make(s):

3.2.18.2.2. Type(s):

3.2.18.2.3. Emission-related adjustment possibilities:

3.2.18.3. Further documentation

3.2.18.3.1. Description of the safeguarding of the catalyst at switch-over from petrol to hydrogen or back:

- 3.2.18.3.2. System lay-out (electrical connections, vacuum connections compensation hoses, etc.):
- 3.2.18.3.3. Drawing of the symbol:
- 3.2.19. H2NG fuelling system: yes/no (*)
- 3.2.19.1. Percentage of hydrogen in the fuel (the maximum specified by the manufacturer):
- 3.2.19.2. EC type-approval number according to UN/ECE Regulation No 110(**).....
- 3.2.19. 3. Electronic engine management control unit for H2NG fuelling
 - 3.2.19. 3.1. Make(s):
 - 3.2.19. 3.2. Type(s):
 - 3.2.19. 3.3. Emission-related adjustment possibilities:.....
- 3.2.19. 4. Further documentation
 - 3.2.19. 4.1. Description of the safeguarding of the catalyst at switch-over from petrol to H2NG or back:
 - 3.2.19. 4.2. System lay-out (electrical connections, vacuum connections compensation hoses, etc.):
 - 3.2.19. 4.3. Drawing of the symbol:";

*Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable)

**OJ L72, 14.3.2008, p. 113.";

(iv) The following points 3.3. to 3.3.2.4. are inserted:

- "3.3. Electric motor
 - 3.3.1. Type (winding, excitation):.....
 - 3.3.1.1. Maximum hourly output:Kw
 - 3.3.1.2. Operating voltage:.....V
- 3.3.2. Battery
 - 3.3.2.1. Number of cells:
 - 3.3.2.2. Mass:kg
 - 3.3.2.3. Capacity:Ah (Amp-hours)
 - 3.3.2.4. Position:";

(v) Point 3.4.8 of Appendix 3 is replaced by the following:

"3.4.8. Vehicle electric rangekm (in accordance to Annex 9 to UN/ECE Regulation No 101 (*)

* OJ L158, 19.6.2007, p. 34."

(vi) Points 3.5.2.1. to 3.5.2.3. are replaced by the following:

"3.5.2.1. Fuel consumption (urban conditions).....l/100 km or m³/100 km or kg/100 km (*)

3.5.2.2. Fuel consumption (extra-urban conditions).....l/100 km or m³/100 km or kg/100 km (*)

3.5.2.3. Fuel consumption (combined).....l/100 km or m³/100 km or kg/100 km (*)";

* Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable)

(vii) The following points 3.5.3. to 3.5.4.3. are inserted:

"3.5.3 Electric energy consumption for pure electric vehicles..... Wh/km

3.5.4. Electric energy consumption for externally chargeable hybrid electric vehicles

3.5.4.1. Electric energy consumption (Condition A, combined)..... Wh/km

3.5.4.2. Electric energy consumption (Condition B, combined)..... Wh/km

3.5.4.3. Electric energy consumption (weighted combined)..... Wh/km";

2. Annex III is amended as follows:

(a) In point 3.4, the following text is added:

$$\text{"For H2NG } d = \frac{9,104 \cdot A + 136}{1.524,152 - 0,583A} \text{ g/l}$$

A being the quantity of NG/biomethane within the H2NG mixture, expressed in per cent volume";

(b) Point 3.8 is replaced by the following:

"3.8. The second subparagraph of paragraph 1.3 of Appendix 8 to Annex 4 shall be understood as:

"... The dilution factor is calculated as follows:

For each reference fuel, except hydrogen

$$DF = \frac{X}{C_{CO_2} + (C_{HC} + C_{CO}) \cdot 10^{-4}}$$

For a fuel of composition $C_xH_yO_z$, the general formula is:

$$X = 100 \frac{x}{x + \frac{y}{2} + 3,76 \cdot \left(x + \frac{y}{4} - \frac{z}{2} \right)}$$

In particular for H2NG, the formula is:

$$X = \frac{65,4 \cdot A}{4,922A + 195,84}$$

For hydrogen, the dilution factor is calculated as follows:

$$DF = \frac{X}{C_{H_2O} - C_{H_2O-DA} + C_{H_2} \cdot 10^{-4}}$$

For the reference fuels contained in Annex IX, the values of "X" are as follows:

Fuel	X
Petrol (E5)	13,4
Diesel (B5)	13,5
LPG	11,9
NG/Biomethane	9,5
Ethanol (E85)	12,5
Ethanol (E75)	12,7
Hydrogen	35,03

In these equations:

C_{CO_2} = concentration of CO_2 in the diluted exhaust gas contained in the sampling bag, expressed in per cent volume,

C_{HC} = concentration of HC in the diluted exhaust gas contained in the sampling bag, expressed in ppm carbon equivalent,

C_{CO} = concentration of CO in the diluted exhaust gas contained in the sampling bag, expressed in ppm,

C_{H_2O} = concentration of H₂O in the diluted exhaust gas contained in the sampling bag, expressed in per cent volume,

C_{H_2O-DA} = concentration of H₂O in the air used for dilution, expressed in per cent volume,

C_{H_2} = concentration of hydrogen in the diluted exhaust gas contained in the sampling bag, expressed in ppm,

A = quantity of NG/biomethane within the H₂NG mixture, expressed in per cent volume.";

3. In Annex IV, Appendix 1, point 2.2, first sub-paragraph, the following text is added:

$$\frac{1,256 \cdot A + 136}{0,654 \cdot A}$$

"- for H₂NG:

A being the quantity of NG/biomethane within the H₂NG mixture, expressed in per cent volume.";

4. In Annex IX, section A, subsection 1, the following is added :

"Type: Hydrogen for internal combustion engines

Characteristics	Units	Limits		Test method
		minimum	maximum	
Hydrogen purity	% mole	98	100	ISO 14687-1
Total hydrocarbon	µmol/mol	0	100	ISO 14687-1
Water ⁽¹⁾	µmol/mol	0	(2)	ISO 14687-1
Oxygen	µmol/mol	0	(2)	ISO 14687-1
Argon	µmol/mol	0	(2)	ISO 14687-1
Nitrogen	µmol/mol	0	(2)	ISO 14687-1
CO	µmol/mol	0	1	ISO 14687-1
Sulphur	µmol/mol	0	2	ISO 14687-1
Permanent particulates ⁽³⁾				ISO 14687-1
⁽¹⁾ Not to be condensed. ⁽²⁾ Combined water, oxygen, nitrogen and argon: 1.900 µmol/mol. ⁽³⁾ The hydrogen shall not contain dust, sand, dirt, gums, oils, or other substances in an amount sufficient to damage the fuelling station equipment of the vehicle (engine) being fuelled.				

Type: Hydrogen for fuel cell vehicles

Characteristics	Units	Limits		Test method
		minimum	maximum	
Hydrogen fuel ⁽¹⁾	% mole	99,99	100	ISO 14687-2
Total gases ⁽²⁾	µmol/mol	0	100	
Total hydrocarbon	µmol/mol	0	2	ISO 14687-2
Water	µmol/mol	0	5	ISO 14687-2
Oxygen	µmol/mol	0	5	ISO 14687-2
Helium (He), Nitrogen (N ₂), Argon (Ar)	µmol/mol	0	100	ISO 14687-2
CO ₂	µmol/mol	0	2	ISO 14687-2
CO	µmol/mol	0	0,2	ISO 14687-2
Total sulphur compounds	µmol/mol	0	0,004	ISO 14687-2
Formaldehyde (HCHO)	µmol/mol	0	0,01	ISO 14687-2
Formic acid (HCOOH)	µmol/mol	0	0,2	ISO 14687-2
Ammonia (NH ₃)	µmol/mol	0	0,1	ISO 14687-2
Total halogenated compounds	µmol/mol	0	0,05	ISO 14687-2
Particulates size	µm	0	10	ISO 14687-2
Particulates concentration	µg/l	0	1	ISO 14687-2
<p>⁽¹⁾ The hydrogen fuel index is determined by subtracting the total content of non-hydrogen gaseous constituents listed in the table (Total gases), expressed in mole percent, from 100 mole percent. It is less than the sum of the maximum allowable limits of all non-hydrogen constituents shown in the Table.</p> <p>⁽²⁾ The value of total gases is summation of the values of the non-hydrogen constituents listed in the table, except the particulates."</p>				

Type: H2NG

The hydrogen and the NG/biomethane fuels composing a H2NG mixture, must comply separately with their corresponding characteristics, expressed in this Annex.";

5. Annex XII is amended as follows:

(a) The title is replaced by the following:

"DETERMINATION OF CO₂ EMISSIONS , FUEL CONSUMPTION, ELECTRIC ENERGY CONSUMPTION AND ELECTRIC RANGE";

(b) The introduction is replaced by the following:

"This Annex sets out the requirements for the measurement of CO₂ emissions, fuel consumption, electric energy consumption and electric range";

(c) Point 3.1. is replaced by the following:

"3.1. The technical requirements and specifications for the measurement of CO₂ emissions, fuel consumption, electric energy consumption and electric range shall be those set out in Annexes 6 to 10 to UN/ECE Regulation 101 with the exceptions specified below";

(d) The introductory sentence of section 1.4.3 is replaced by the following:

"1.4.3. The fuel consumption, expressed in litres per 100 km (in the case of petrol, LPG, ethanol (E85) and diesel), in m³ per 100 km (in the case of NG/biomethane and H₂NG) or in kg per 100 km (in the case of hydrogen) is calculated by means of the following formulae:";

(e) The following points (f) and (g) are added:

"(f) for vehicles with a positive ignition engine fuelled by H₂NG:

$$FC = \frac{910,4 \cdot A + 13.600}{44,655 \cdot A^2 + 667,08 \cdot A} \left(\frac{7,848 \cdot A}{9,104 \cdot A + 136} \cdot HC + 0,429 \cdot CO + 0,273 \cdot CO_2 \right)$$

(g) for vehicles fuelled by gaseous hydrogen:

$$FC = 0,024 \cdot \frac{V}{d} \cdot \left[\frac{1}{Z_2} \cdot \frac{p_2}{T_2} - \frac{1}{Z_1} \cdot \frac{p_1}{T_1} \right]$$

Under previous agreement with the type-approval authority, and for vehicles fuelled either by gaseous or liquid hydrogen, the manufacturer may choose as alternative to the method above, either the formula

$$FC = 0,1 \cdot (0,1119 \cdot H_2O + H_2)$$

or a method according to standard protocols such as **SAE J2572**.";

(f) The second paragraph is replaced by the following

"In these formulae:

FC = the fuel consumption in litre per 100 km (in the case of petrol, ethanol, LPG, diesel or biodiesel) in m³ per 100 km (in the case of natural gas and H₂NG) or in kg per 100 km in the case of hydrogen.

HC = the measured emission of hydrocarbons in g/km

CO = the measured emission of carbon monoxide in g/km

CO₂ = the measured emission of carbon dioxide in g/km

H₂O = the measured emission of H₂O in g/km

H₂ = the measured emission of H₂ in g/km

A = quantity of NG/biomethane within the H₂NG mixture, expressed in per cent volume

D = the density of the test fuel.

In the case of gaseous fuels D is the density at 15°C.

d = the theoretical distance covered by a vehicle tested under the type 1 test in km.

*p*₁ = pressure in gaseous fuel tank before the operating cycle in Pa;

*p*₂ = pressure in gaseous fuel tank after the operating cycle in Pa;

*T*₁ = temperature in gaseous fuel tank before the operating cycle in K.

*T*₂ = temperature in gaseous fuel tank after the operating cycle in K.

*Z*₁ = compressibility factor of the gaseous fuel at *p*₁ and *T*₁

*Z*₂ = compressibility factor of the gaseous fuel at *p*₂ and *T*₂

V = inner volume of the gaseous fuel tank in m³

The compressibility factor shall be obtained from the following table

p(bar)\ T(k)	33	53	73	93	113	133	153	173	193	213	233	248	263	278	293	308	323	338	353
5	0,8589	0,9651	0,9888	0,9970	1,0004	1,0019	1,0026	1,0029	1,0030	1,0028	1,0035	1,0034	1,0033	1,0032	1,0031	1,0030	1,0029	1,0028	1,0027
100	1,0508	0,9221	0,9911	1,0422	1,0659	1,0757	1,0788	1,0785	1,0765	1,0705	1,0712	1,0687	1,0663	1,0640	1,0617	1,0595	1,0574	1,0554	1,0535
200	1,8854	1,4158	1,2779	1,2334	1,2131	1,1990	1,1868	1,1757	1,1653	1,1468	1,1475	1,1413	1,1355	1,1300	1,1249	1,1201	1,1156	1,1113	1,1073
300	2,6477	1,8906	1,6038	1,4696	1,3951	1,3471	1,3123	1,2851	1,2628	1,2276	1,2282	1,2173	1,2073	1,1982	1,1897	1,1819	1,1747	1,1680	1,1617
400	3,3652	2,3384	1,9225	1,7107	1,5860	1,5039	1,4453	1,4006	1,3651	1,3111	1,3118	1,2956	1,2811	1,2679	1,2558	1,2448	1,2347	1,2253	1,2166
500	4,0509	2,7646	2,2292	1,9472	1,7764	1,6623	1,5804	1,5183	1,4693	1,3962	1,3968	1,3752	1,3559	1,3385	1,3227	1,3083	1,2952	1,2830	1,2718
600	4,7119	3,1739	2,5247	2,1771	1,9633	1,8190	1,7150	1,6361	1,5739	1,4817	1,4823	1,4552	1,4311	1,4094	1,3899	1,3721	1,3559	1,3410	1,3272
700	5,3519	3,5697	2,8104	2,4003	2,1458	1,9730	1,8479	1,7528	1,6779	1,5669	1,5675	1,5350	1,5062	1,4803	1,4570	1,4358	1,4165	1,3988	1,3826
800	5,9730	3,9541	3,0877	2,6172	2,3239	2,1238	1,9785	1,8679	1,7807	1,6515	1,6521	1,6143	1,5808	1,5508	1,5237	1,4992	1,4769	1,4565	1,4377
900	6,5759	4,3287	3,3577	2,8286	2,4978	2,2714	2,1067	1,9811	1,8820	1,7352	1,7358	1,6929	1,6548	1,6207	1,5900	1,5623	1,5370	1,5138	1,4926

In the case that the needed input values for p and T are not indicated in the table, the compressibility factor shall be obtained by linear interpolation between the compressibility factors indicated in the table, choosing the ones that are the closest to the sought value."