

ANNEX

TO EUROMOT GUIDANCE ON THE IMPLEMENTATION OF ARTICLE 35 OF REGULATION (EU) 2016/1628

JULY 2024

Specific guidance for spark
ignition engines fuelled
solely on hydrogen

Link to document:

[EUROMOT-Guidance-on-the-
Implementation-of-Article-
35-of-Regulation-EU-2016-
1628.pdf](#)



H₂
HYDROGEN

DISCLAIMER

This document reflects the view of EUROMOT, as regards the compatibility of hydrogen as a fuel for internal combustion engines, with the requirements of Regulation (EU) 2016/1628, Regulation (EU) 2017/654, Regulation (EU) 2017/655 and Regulation (EU) 2017/656, and it must not be considered or intended as a legally binding text for any reason whatsoever.

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Only the text of the Regulation and of the relevant supplementing legislation is authentic in law.

Accordingly, in case of discrepancies between the content and interpretation of this document and the text of the legislation (Regulation (EU) 2016/1628 and the relevant supplementing legislation), the legislation must be applied.

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1 INTRODUCTION

This supplemental document addresses specific incompatibilities with Regulation (EU) 2016/1628 and its Delegated and Implementing Acts, that arise from the use of mono-fuelled lean burn hydrogen internal combustion engines, and the alternative processes that may be used to fulfil the obligations of Article 35.

2 BACKGROUND

All engines that are placed on the market in the EU are required to provide the levels of environmental protection laid out in Regulation (EU) 2016/1628.

An internal combustion engine fuelled solely by hydrogen, by virtue of utilising a zero-carbon fuel, has no negative environmental implications compared with a Stage V type-approved engine operated on a standard reference fuel. They are expected to meet all substantive requirements, including core emissions standards set by Regulation (EU) 2016/1628 Annex II, therefore ensuring a level of environmental protection that is at least equivalent to the level provided by the requirements of the Regulation.

The existing principle that a parent engine must be tested on a test bench over the specified cycles applicable to the engine (sub-) category and comply with the applicable limit values can still apply in this case. However, the use of hydrogen as a fuel is incompatible with procedural aspects of the Regulation, and its Delegated and Implementing Acts. The specific incompatibilities have been identified in Section 3 of this document, and can be categorised as resulting from the facts that:

- a) Hydrogen is not included as a reference fuel in Regulation (EU) 2016/1628.
- b) The specification and use of instrumentation for the measurement of exhaust emissions from engine operated on carbon containing fuels may require adaptation for use with engines solely fuelled on hydrogen.
- c) The calculation methodology included in Commission Delegated Regulation (EU) 2017/654 is not compatible with non-carbon-containing fuels.
- d) The reporting templates of Commission Delegated Regulation (EU) 2017/656 require adaptation for use with engines solely fuelled on hydrogen.

To provide an internationally accepted and common methodology to resolve the points above, amendments that are compatible with hydrogen combustion have been made to UNECE Regulation 96 and have been adopted by the Contracting Parties of UNECE. These can be directly applied to the equivalent sections of EU Regulations to adapt the normal Stage V test procedures. Full details can be found in document [ECE TRANS WP.29 2024 52e.pdf \(unece.org\)](https://www.unece.org/cees/transport/wp29/2024/wp29_2024_52e.pdf)

The corresponding sections of the Stage V Regulation and the proposed adaptations have been identified below. Where no amendments or exceptions have been listed, the relevant EU Regulation would still apply to hydrogen engines in the same way as they would apply to any other type-approved engine types or families.

3 INCOMPATIBILITIES AND ADAPTATIONS BASED ON THOSE ADOPTED FOR UNECE REGULATION 96

Category a: hydrogen reference fuel

Regulation	Section	Incompatibility	Proposed adaptations
Regulation (EU) 2016/1628	Article 25	Hydrogen is missing from the list of reference fuels.	Permit hydrogen to be used.

Category b: changes to the specification and use of instrumentation

The characteristics of hydrogen engine exhaust must be accounted for to ensure accurate measurement of exhaust emissions. Only certain measurement methods have been validated for the use with hydrogen combustion engines.

Regulation	Section	Incompatibility	Proposed adaptations
Regulation (EU) 2017/654	Annex VI	High water content in the exhaust of hydrogen combustion engines.	All parts of the emissions measurement system should meet calibration and performance checks at the highest exhaust water content expected during the testing.
Regulation (EU) 2017/654	Annex VI	High water content in the exhaust of hydrogen combustion engines	All sample gas carrying components should be maintained at a temperature 10 K above the dew point of the sample gas at the corresponding location.
		For the R96 amendment, only direct measurement of gaseous emissions from raw exhaust has been validated for engines fuelled solely on hydrogen.	The measurement of gaseous exhaust emissions should be conducted from raw exhaust gas.
	Annex VI Section 8 Paragraph 8.1.9.2.3	Hydrogen fuel contains no carbon.	A CO NDIR analyser should have combined H ₂ O and CO ₂ interference that is within ±2 per cent of the expected mean concentration of CO, or 20ppm, whichever is larger.
	Annex VI Section 9	For the R96 amendment, only direct measurement of gaseous emissions from raw exhaust has been validated for engines fuelled solely on hydrogen.	In paragraph 9.2, the dilution procedure should not apply for gaseous emissions.
Annex VI Section 9 Paragraph 9.4.10	Lambda sensor accuracy criteria is missing.	The accuracy of the lambda sensor should be: (a) ±3% of reading for $\lambda < 2$ (b) ±5% of reading for $2 \leq \lambda < 5$ (c) ±10% of reading for $5 \leq \lambda$	

Category c: modifications to the emissions calculation methodology

The calculation methodology for hydrogen internal combustion engines closely follows that of engines operated on carbon containing fuels, with the following modifications:

Regulation	Section	Incompatibility	Proposed adaptations
Regulation (EU) 2017/654	Annex VII Section 2	For the R96 amendment, only the use of mass-based calculations has been validated for engines fuelled solely on hydrogen.	Calculation of gaseous exhaust emissions should only be done from sampling of the raw exhaust and using the mass-based emissions calculations in Section 2.1, incorporating the adaptations below.
Regulation (EU) 2017/654	Annex VII Section 2	Hydrogen fuel contains no carbon.	If the emissions are measured on a dry basis, Equation (7-7) should not be used for engines operated solely on hydrogen.
		Hydrogen fuel contains no carbon.	Equation (7-11) should not be used to calculate u values for engines operated solely on hydrogen. The values in Table A. could be used for the raw exhaust gas u and component densities. Alternatively, Equation (7-12) could be used to calculate u values.
		Hydrogen fuel contains no carbon.	Equation (7-15) or (7-17) should be used to calculate the mass flow rate of the exhaust gas.
		Hydrogen fuel contains no carbon.	Where Equation (7-17) is used to calculate the mass flow rate of the exhaust, then Equation (7-18) should not be used to calculate A/F_{st} , and instead a value of 34.2282 shall be used.
		Hydrogen fuel contains no carbon.	Equation (7-19) should not be used to calculate excess air ratio λ_i and instead λ_i should be measured by a lambda sensor according to Annex VI paragraph 9.4.10.
		Hydrogen fuel contains no carbon.	Calculation of cycle specific CO ₂ using Equation (7-63) should not be required.
	Annex VII Appendix 2	Hydrogen fuel contains no carbon.	The carbon flow check set out in Appendix 2 should not be required. The carbon flow check could be performed on a diesel fuelled engine prior to the installation of the engine operated solely on hydrogen.
Annex IX	There is no reference fuel specification for hydrogen.	The reference fuel should meet the requirements of ISO 14687:2019 Grade D.	

Table A.

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

Fuel	ρ_e	Gas					
		NO_x	CO	HC	CO_2	O_2	CH_4
		$\rho_{gas} [kg/m^3]$					
		2.053	1.250	^a	1.9636	1.4277	0.716
		u_{gas}^b					
Hydrogen	1.1872	0.001729	0.001053	0.000075	0.001654	0.001203	0.000603

^a depending on fuel

^b at $\lambda = 2$, dry air, 273 K, 101.3 kPa

Category d: administrative changes to templates

Regulation	Section	Incompatibility	Proposed adaptations
Regulation (EU) 2017/656	Annex I Appendix 3: Information document template, Paragraphs 2.8.1, 3.14.1	Hydrogen is not included as a fuel type.	“Hydrogen” should be noted as the fuel type.
	Annex IV: EU Type Approval Certificate, Paragraph 2.8.1	Hydrogen is not included as a fuel type.	“Hydrogen” should be noted as the fuel type.
	Annex IV: EU Type Approval Certificate, Paragraph 11.2	Hydrogen fuel contains no carbon.	The CO_2 result is not required.
	Annex V Appendix 1: Table 2	No fuel type codes exist for SI engines solely fuelled on gaseous hydrogen.	SI engines approved and calibrated for gaseous hydrogen should use the fuel type code T.
	Annex VI Appendix 1: Test Report Template, Paragraph 4.5	No fuel information section exists for hydrogen as a fuel.	Paragraph 4.5 should be added as a new paragraph to include information on the make and type of hydrogen fuel used.
	Annex VI Appendix 1: Test Report Template, Paragraphs 9.3.3, 10.2.3, 10.2.6, 10.3, 10.4.2, 11.2	Hydrogen fuel contains no carbon.	The CO_2 result should not be required.

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