

HFCV - SGE

Draft Technical Report - Pollutant Emissions of Hydrogen (H₂) Fuelled Vehicles1. Explanation and Specification of the issue

In legislation the emissions of gaseous pollutants carbon monoxide (CO), hydro carbons (HC), oxides of nitrogen (NO_x) and the emissions of particulate matter (PM) are limited in g/km or g/kWh. Light Duty Vehicles (LDV) and motorcycles are tested on a roller test bench, engines of Heavy Duty Vehicles (HDV) (and comparable engines of other vehicles) are tested on an engine test bench, driving a transient test cycle or steady state test. This test procedure including the test cycle is different for vehicle categories and in national legislation. The concentrations of the emissions are measured and then calculated in g/km or g/kWh.

Evaporative and low temperature emissions (requirements in ECE-R 83 [9]) are only related to gasoline engines and not relevant for H₂ as fuel.

Fuel cell vehicles don't emit one of the above mentioned pollutants, if H₂ is used directly. A fuel cell can also be fuelled with H₂, that was reformed (on vehicle) from a different base fuel (C_xH_y). In case of a reformer (on vehicle), pollutant emissions are relevant, depending on the base fuel and the reforming process.

Theoretically the only component emitted by internal combustion engines (ICE) fueled with H₂ is NO_x. The level of NO_x emissions is depending on the air-H₂ ratio, respectively exhaust gas temperature and the layout of the aftertreatment system (e.g. catalyst). The use of H₂ is possible in positive- and compression ignition engines.

In cases where H₂ is used together with other fuels (H₂-bi-fuel, H₂-flex-fuel, H₂-dual-fuel), all the other pollutants become relevant. H₂-bi-fuel systems (BMW) or hydrogen mixtures (e.g. with CNG, [4]) are interesting solutions during the introduction phase of H₂ vehicles, until the infrastructure with H₂ fuelling stations is more developed. For the time being BMW and Mazda (LDV) and MAN (buses, HDV) are the only manufacturers producing vehicles

with ICE using H₂ as fuel. It can be assumed that the level of the pollutant emissions of the three above mentioned vehicles are below the mandatory limit values.

The level of NO_x emissions of H₂-fuelled ICE is averaged by 2 - 30 % of the existing mandatory limits of NO_x in Europe and USA [10]. The level of the other pollutants is nearly zero. Theoretically they should be equal to zero, but practically the small amount of emissions are caused by lube oil losses, or in case of H₂-bi-fuel concepts, because the injection of the other fuel is pre-activated during H₂-fuel mode.

H₂ can be stored liquid (LH₂) or compressed gaseous (CGH₂). The influence on pollutant emissions by the type of storage is not relevant. The only need is to define different reference H₂-fuel and reference H₂-gas for emission testing.

Engines and fuel cells are emitting also non limited components, e.g. ammonia, hydrocyanic acid, organic amine, aldehyde, sulfur dioxide. Today there is no evidence that ICE and fuel cells are emitting any non limited component, that causes serious environmental or health problems.

2. Application and Scope

2.1. Vehicle categories

In principle all vehicle categories defined in Special Resolution No.1 [1] can be powered by H₂:

- passenger car (category 1-1 vehicle)
- bus (category 1-2 vehicle)
- truck (category 2 vehicle)
- 2 or 3 wheeler (category 3 vehicle)

Also possible, is the use of H₂ in agricultural and forestry tractors [2] and Non Road Mobile Machinery (NRMM) [3]. Today there is not big interest for marketing of such solutions. Therefore these vehicle categories will not be further covered by this report - out of scope.

2.2. Propulsion system

Internal combustion engine (ICE), positive or compression ignition, or in combination with an electric engine (Hybrid Electric Vehicle).

Also possible, but not developed for the time being, is a combination of ICE and Fuel Cell (Hybrid Vehicle) - out of scope.

2.3. Reformer (on vehicle)

For the time being it's improbable that a vehicle in serial production will be equipped with reformer technology. Furthermore a procedure to measure the pollutant emissions from the reformer process is not defined. Therefore this technology will not be further covered by this report - out of scope.

2.4. Fuel Types

- H2-fuel
- H2-bi-fuel with gasoline, diesel, CNG or LPG
- H2 blend/mixture (flex-fuel / dual-fuel) with gasoline, diesel, CNG or LPG
- H2 reformed (on board) from gasoline, diesel, LPG, CNG, methanol - out of scope (see chapter 2.3.)

3. Definitions

“Calculation method” - means the calculation method of mass emissions of pollutants, e.g. defined in appendix 8 of ECE-R 83 [9].

“Reference fuel / Reference gas” – means the definition of specifications of the fuel (LH2) or gas (CGH2) taken for the emission tests.

“H2-fuel-vehicle” – means a vehicle that primarily runs on H2 but may also have a petrol system for emergency purposes or starting only, where the petrol tank does not contain more than 15 litres of petrol.

(this definition is in line with the definition of "mono fuel gas vehicle" in [13])

"H2-bi-fuel vehicle" means a vehicle that can run part-time on H2 and also part time either on gasoline, diesel, LPG or CNG

"Flex-fuel vehicle" - means a vehicle with one fuel storage system that can run on different mixtures of two or more fuels [13].

"Dual-fuel vehicle" – means a vehicle with two storage systems for different fuels, where the both fuels are mixed either in the intake system or during injection into the combustion chamber.

"Hybrid vehicle" - means a vehicle with at least two different energy converters and two different energy storage systems (on vehicle) for the purpose of vehicle propulsion [9], [13]. ([9] and [13] also contains a definition for a "hybrid electric vehicle")

4. Overview on existing Regulations & Standards

4.1. Passenger cars

The legislation concerning pollutant emissions from category 1-1 vehicles is not harmonised. Different test cycles, measurement methods, reference fuels and limit values are applicable. None of the existing Regulations includes test methods and requirements for H2 vehicles (ICE). The current European Euro 5/6 Regulation [13] already mentions H2 as fuel, but specific test procedures for H2 will be defined at a later stage.

A (possible) GTR project to develop a worldwide harmonised light vehicles test procedure (WLTP) is under preparation [5]. The documentation in [5] includes a comprehensive overview of the existing national legislation on pollutant emissions. Currently the emission measurement of H2 vehicles is not included in the draft roadmap.

ECE-R 83 [9] contains requirements regarding the pollutant emissions for mono-fuel and bi-fuel vehicles (gasoline, diesel, CNG, LPG). ECE-R 83 will be amended soon to be in line with the European Euro 5/6 requirements [13], including an approach for flex fuel (gasoline and Ethanol).

4.2. Heavy duty vehicles

With GTR No. 4 [6], a world wide harmonised emission test procedure for heavy duty vehicles is established (category 1-2 and category 2 vehicles). The Appendix to GTR No. 4 (Technical Report) [6] includes an overview about the existing national emission legislation for heavy duty vehicles and relevant standards. Harmonised performance requirements are not included in GTR No. 4 for the time being. H2 vehicles are not covered by GTR No.4.

4.3. 2/3 wheelers

With GTR No. 2 [7], a world wide harmonised emission test procedure for 2-wheeled motorcycles is established. The Appendix to GTR No. 4 (Technical Report) [7] includes an overview about the existing national emission legislation for 2-wheelers and relevant standards. Performance requirements (limit values) are not included at the moment, but AC.3 mandated the WMTC informal group to develop a proposal for the harmonisation of limit values. H2 vehicles are not covered by GTR No.4.

The legislation concerning pollutant emissions from mopeds (< 50 ccm, < 50 km/h) and three wheelers is not harmonised. Different test cycles, measurement methods, reference fuels and limit values are applicable. None of the existing Regulations includes test methods and requirements for H2 vehicles (ICE).

4.4. Reference Fuel and Reference Gas

The international standards ISO 14687 [8] and SAE J2719 [11] defines specifications for H2 as fuel. On this basis a reference fuel and reference gas can be defined for the purpose of H2 consumption measurement as well as for the purpose of measurement of NO_x emissions. The issue of reference fuel and reference gas is described in more detail in Technical Report II [12].

A specification for H2 as flex-fuel either as dual-fuel is not existing for the time being.

5. Work to be done and state of research

- A calculation method for NOx emissions from ICE fuelled with H2 needs to be developed.
- Concerning H2-flex-fuel and H2-dual fuel, experience and emission test data are required for the development of a regulatory approach. This includes work on specification of reference fuel (s) and the definition of a calculation method (emissions).

6. Regulatory approach

6.1 Need for regulation

NOx emissions of vehicles with ICE using H2-fuel and pollutant emissions of H2-bi-fuel vehicles should be regulated. The level of limit values will be decided by national regulatory decision processes, but probably the limit values will be the same as for conventional vehicles.

6.2. Open issues and need for specification

- Definition of H2 reference fuel and gas, if possible accepted worldwide and applicable for all vehicle categories.
- Definition of the regulatory approaches (e.g. worst case, measurement with both fuels) for H2-bi-fuel vehicles (and H2-flex-fuel, H2-dual-fuel).
- If needed, a definition for a H2-bi-fuel vehicle, to separate clear from H2-flex-fuel or H2-dual-fuel.

6.3. Assessment of harmonisation - development of a GTR

In case of HDV and 2-wheeled motorcycles a world wide harmonisation is possible, because GTR's for the measurement of pollutant emissions already exists. This is not the case for LDV, and the development of a world wide harmonised test cycle and measurement procedure especial for LDV using H2 in ICE is not efficient and feasible.

In case motorcycles or HDV with ICE using H2 are ready for marketing, an amendment of GTR No. 2 (WMTC) or GTR No. 4 (WHDC) can easily be developed. Such amendments of

the existing GTR's only need the definition of the reference fuel, the calculation method for NOx (H2-fuel) and the definition of the H2-bi-fuel approach. This can be considered as a mid-term activity for both vehicle categories.

For LDV it should be considered to introduce a reference fuel (gas), a calculation method for the NOx emissions and the definition of the H2-bi-fuel approach with the WLTP GTR [5]. In the meantime, existing national legislation or ECE-R 83 can be amended.

As a conclusion, it is not proposed to develop a special GTR for the measurement and limitation of pollutant emissions of H2 vehicles.

7. References

[1] Special Resolution No.1; Concerning the common definitions of vehicle categories, masses and dimensions (S.R.1); TRANS/WP.29/1045

[2] Consolidated Resolution of the construction of vehicles (R.E.3); Annex 7; TRANS/WP.29/78/Rev.1

[3] NRMM - GTR development;
http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/nrmm_mtng_minutes.html

[4] Regulation (EC) no 79/2009; Official Journal of the European Union; L 35/32

[5] WLTP - GTR roadmap phase;
<http://www.unece.org/trans/main/wp29/wp29wgs/wp29grpe/wltp01.html>

[6] GTR No. 4; Worldwide harmonised heavy-duty certification procedure (WHDC);
<http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29registry/gtr4.html>

[7] GTR No 2; Worldwide harmonised motorcycle emission certification procedure (WMTC); <http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/wp29registry/gtr2.html>

[8] ISO 14687 - Hydrogen fuel -- Product specification

[9] ECE-R 83: <http://www.unece.org/trans/main/wp29/wp29regs81-100.html>

[10] H. Eichlseder, M. Klell; Wasserstoff in der Fahrzeugtechnik; Vieweg + Teubner Verlag; Wiesbaden 2008

[11] SAE J2719 - <...>

[12] Draft Technical Report - H2SGE-IP-01, December 2008

[13] Regulations (EC) No 2007-715 and No 2008-692