

# **Draft Technical Report**

## **Energy and Operation Performance of Hydrogen (H<sub>2</sub>) fuelled Vehicles**

Rev. 1 of the draft report:

### **Fuel consumption, External Electrical Consumption and Maximum speed measurement.**

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## ***Introduction***

This report is related to the Hydrogen use in vehicle application and relevant measurement of energy and operation performance of the vehicle and components.

The following applications are considered (out of the matrix previously established)

1. Fuel cell system: stack, components,
2. Fuel cell vehicles
3. Hybrid fuel cell vehicles
4. Hybrid H<sub>2</sub> - I.C.E. vehicles

For these applications, the following aspects are considered as appropriate:

- Fuel consumption
- External Electricity Consumption of Hybrid Vehicles
- Maximum speed

The scope of the report is to list and analyse the elements necessary to prepare harmonised standards/regulations on this matter and ultimately GTRS, starting from existing normative documents and data coming from research result.

The report addresses the following content:

- Overview of existing regulation, standards and possible links
- Overview of the state-of-art
- Missing standardisation topics
- Ongoing/finalised research activities relevant to the matter
- Possible further research needed

The following figure presents the International Standards and Regulation Bodies dealing with Hydrogen and Fuel Vehicles with the relevant fields of action and links.

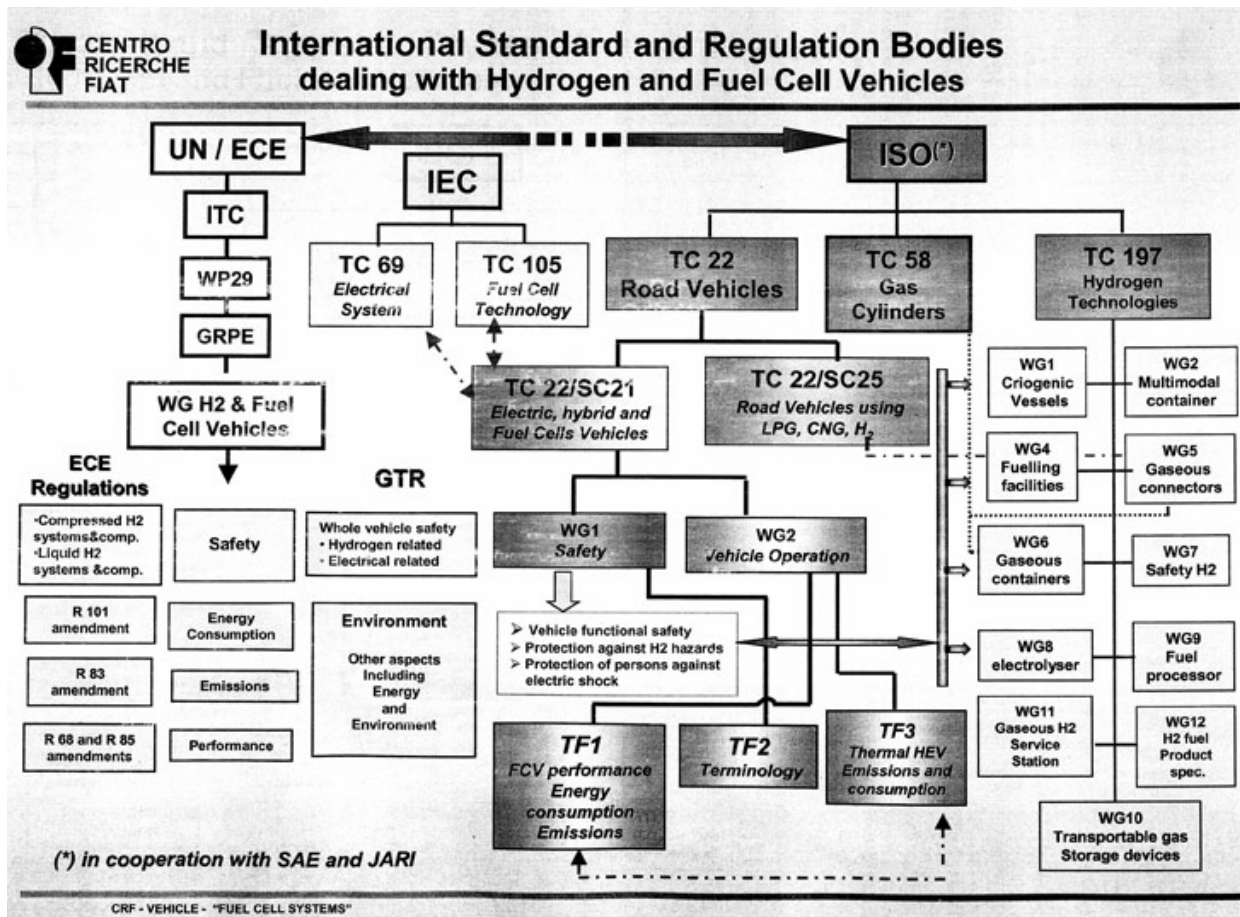


Figure 1 International Standard and Regulation Bodies dealing with H<sub>2</sub> and FC vehicles

## A) Fuel consumption

### A1. Explanation and specification of the issue

In legislation the fuel consumption of Passenger Cars, Light Duty Vehicles and Motorcycles is tested on a roller test bench; for Heavy Duty Vehicles are tested on an engine test bench, following test cycle or steady state test.

National prescriptions provide specifications for test procedures and driving profile both for regulation and for standard.

Determination of fuel consumption is a fundamental issue for all vehicle categories, since it constitutes:

- an element required for certification/homologation
- a parameter for possible definition of taxation
- a common basis for comparing energy performance of different vehicles and different power train solutions
- a basis to determine the "Well To Wheel" energy effectiveness of the various solutions with respect to the primary energy source.

## A2 Application and Scope

### A2.1 Vehicle categories

In principle all vehicle categories defined in Special Resolution No.1 [1] can be powered by H<sub>2</sub>:

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

### A2.2 Propulsion systems

- Pure Fuel Cell Vehicle
- Fuel Cell Hybrid (Fuel Cell and Rechargeable Electric Storage) Vehicle
- Fuel Cell Systems and components: Stack (inherent characterization)
- I.C.E. – H<sub>2</sub> (I.C.E. fuelled by Hydrogen) Hybrid vehicle
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## A3 Definitions

The definition of the different propulsion systems and components should be based on those given in Standard, Regulation and Technical Report, with appropriate harmonization.

## A4 Overview on existing Regulation and Standard

### A4.1 Fuel cell systems: Stack and Components

Standards existing or under development by:

#### ISO/TC 197 Hydrogen technologies

ISO 14687: Hydrogen fuel-product specification

ISO 14687: Hydrogen fuel-product specification

Part 2: Proton exchange membrane (PEM) fuel cell application for road vehicles

#### IEC/TC 105 Fuel cell technologies

IEC 62282-1:2005 Fuel cell technologies - Part1: Terminology (published)

IEC 62282-2:2004 Fuel cell technologies - Part 2: Fuel cell modules (published)

IEC/CDV 62282-3-2 Fuel cell technologies - Part 3-2: Stationary fuel cell power plants - Test methods for the performance

IEC/PWI 62282-4 Fuel cell technologies - Part 4: Fuel cell system for propulsion and auxiliary power unit

## SAE

SAE J 2615 Reference test procedures of fuel cell systems for automotive application

SAE J 2616 Performance test procedures for the fuel processor systems for automotive application

SAE J 2617 Performance test procedures of PEM fuel cell stack subsystem for automotive application

### A4.2 Pure Fuel Cell Vehicles

#### Existing Regulations/Standards:

- Regulation UN ECE R 101

The R 101 provides methods for consumption measurement of ICE vehicle, with carbon based fuel, battery electric vehicles and hybrid electric vehicles.

The structure is prepared to incorporate procedures for ICE vehicles fuelled with H<sub>2</sub> and fuel cell vehicles pure or hybrid.

A draft proposal was developed by the consortium of Companies (lead by RTWH-Aachen) acting on EU Programme FUEVA.

- Standard ISO 23828:

“Fuel Cell Road Vehicles-Energy Consumption measurement-Vehicles fuelled with compressed hydrogen”, developed by ISO/TC22/SC21.

This standard deals with the measuring methods of hydrogen and the procedures to test the vehicle.

The procedure prescribes the test on a chassis dynamometer.

The test consists of the vehicle preconditioning measurement over a reference driving schedule.

The running mode, including the dynamometer setting, is prescribed differently in the various Regions (Japan, Europe, and U.S.A.).

The prescribed methods are the following: (see Annex to the Standard)

1. Pressure method (normative)
2. Gravimetric method (normative)
3. Flow method (normative)
4. Current method (informative)

The three normative methods (pressure, gravimetric and flow) are considered equivalent, insofar they can produce results within a precision of  $\pm 1\%$ , according to the measurements done up to now.

They are left open according to the test tools of manufacturer and/or testing institution.

- Standards from ISO TC 197 “Hydrogen technologies”

ISO 14687:1999 / Cor. 1:2001 “Hydrogen fuel-Product specification”

ISO/TS 14687-2:2008 “Hydrogen fuel-Product specification- Part 2: Proton exchange membrane (PEM) fuel cell application for road vehicles

ISO/DIS 16110-2 “Hydrogen generators using fuel processing technologies-Part 2: procedure to determine efficiency

### **Missing standards**

Methods for consumption measurement of H<sub>2</sub> stored in liquid phase and in Metal Hydride tank. Recommendation is given for development of these standards; insofar the technology is already in practical applications.

#### **A4.3 Hybrid Fuel Cell Vehicles**

The standard ISO 23828 is applicable to Fuel Cell road vehicles in general, fuelled with compressed H<sub>2</sub>, both pure FC and Hybrids; the different procedures are put in evidence inside the standard.

A missing standard, to be possibly developed, is related to Fuel Cell Hybrid Vehicle-Energy consumption measurement- Externally chargeable vehicles (plug-in vehicles).

This standard should cover the procedure to measure both Hydrogen and Electricity for FC Vehicle plug-in, similarly to the standard for ICE Hybrid Electric Vehicles externally chargeable vehicles.

#### **A4.4 ICE-H<sub>2</sub> Hybrid Vehicles**

The prescription for fuel consumption measurement of ICE-H<sub>2</sub> Hybrid Vehicles could be derived from those for Hybrid Electric road vehicles (ISO 23274) non externally chargeable, including the provisions for H<sub>2</sub> measurements as prescribed in ISO 23828.

### **A5 Overview of the state of art**

At the level of international standard, a standard ISO (TC 22/SC21) is presently under study, concerning the measurement of fuel consumption and emissions for Externally Rechargeable Hybrid Vehicles.

### **A6 On going finalised research**

The EU Programme FUEVA (lead by RTWH – Aachen) includes research related to test and validate on vehicle the procedures for hydrogen consumption measurement.

### **A7 Further research needed**

Research related to procedure for H<sub>2</sub> consumption measurement of H<sub>2</sub> stored in liquid phase or in Metal Hydride tank.

## **A8 Assessment of the harmonization**

The GTRs should be established consistently with common agreement on the topics.

Bases for GTRs could be standards and regulation (national or regional) existing or under development. The related content should be, therefore, harmonized on international basis.

## ***B) External Electrical Consumption***

### **B1 Explanation and specification of the issue**

The external electrical consumption occurs for dual energy powered vehicles (H<sub>2</sub> and electricity). This is the case of either Fuel Cell Hybrid (battery electric with fuel cell electricity generator), or I.C.E.- H<sub>2</sub> supplied Electric Hybrid.

### **B2 Application and scope**

#### **B2.1 Vehicle categories**

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

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

#### **B2.2 Propulsion systems**

- Fuel cell hybrid (Fuel Cell and Rechargeable Electric Storage) Vehicle
- I.C.E. – H<sub>2</sub> (I.C.E. powered by Hydrogen) Hybrid

### **B3 Overview on existing Regulation and Standard**

#### **B3.1 Fuel Cell Hybrid Vehicles**

For Passenger Cars and Light Duty Vehicles regulation UN ECE R101 provides methods for consumption measurement of ICE Vehicles, with carbon based fuel, Battery Electric and Hybrid Electric Vehicles. The structure could incorporate Fuel Cell Vehicles Hybrid Vehicles

The external electricity consumption for hybrid vehicles can be derived from procedures included in the standard ISO under development related to Hybrid-Electric road vehicles externally chargeable (plug-in Hybrid), which is presently under development (ISO/WD 23274-2).

## ***C) Maximum speed measurement – Engine Power measurement***

### **C1 Explanation and specification of the issue**

The measurement of the maximum speed for electric vehicles is subject to the consideration of the performance variation with the State Of Charge of the battery and with the thermal status of the electric motor.

For these reasons, standard prescriptions exist to consider, for vehicle characterization, the top speed and the maximum 30 min. speed.

Similar provisions exist for the measurement of the engine power.

### **C2 Application and scope**

#### **C2.1 Vehicle categories**

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

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

#### **C2.2 Propulsion system**

- Pure Fuel Cell Vehicles
- Fuel Cell Hybrid Vehicles
- I.C.E. – H<sub>2</sub> Hybrid Vehicles

### **C3 Overview on existing Regulation and Standard**

A technical report has been recently developed by ISO TC 22/SC 21, regarding Fuel Cell Vehicles maximum speed (pure and hybrid).

This TR, which is presently being issued, is based on the harmonisation of the following documents

- UN ECE Regulation R68- Amendment 1: Uniform provisions concerning the approval of power-driven vehicles including pure electric vehicles with regards to the measurement of the maximum speed
- ISO 8715: Electric Road Vehicles-Road operating characteristics

For ICE-H<sub>2</sub> Hybrid Vehicle, the maximum speed measurement could be done following the general provision of R 68.

#### **Engine Power**

Regulation UN ECE R.85 prescribes test for maximum power and maximum 30 min power for electric vehicles.



### Reference documents

Fuel quality and terminology are topics which should be considered for all applications.

The relevant documents are reported in table 2.

**Table 1 Standards/Regulations existing, to be developed or to be adapted for application to Hydrogen and Fuel Cell Systems/Vehicles**

Topic		H2 Stack and Components APU Generating Unit	FC(pure)Vehicle	FC Hybrid Vehicle	I.C.E.-H2 Vehicle      Hybrid
Fuel Consumption		<b>IEC 62282-2 (2004)</b> <b>SAE 2617</b> <b>ISO 14687</b> Hydrogen Fuel-product specification- Part 2 Proton exchange membrane (PEM) <b>ISO 13985</b> Liquid Hydrogen Land Vehicles Fuel Tanks <b>ISO/TS 16111 (2006)</b> Transportable gas storage devices-Hydrogen absorbed in reversible metal hydrid.	<b>ISO 23828</b> Fuel Cell road Vehicles-Hydrogen consumption measurement -Vehicles fuelled with compressed H2 To be developed: -Vehicles fuelled with liquid H2 To be developed: -Vehicles fuelled with H2 absorbed in MH <b>R101</b> (to be adapted for FC Vehicles inclusion)	To be developed: Fuel Cell Hybrid Vehicle-Energy consumption measurement-Externally chargeable vehicles.	<b>R101</b> (Applicable for fuel consumption to ICE Hybrid, to adapted for H2 use)
External Electrical Consumption		-	-	<b>ISO/WD 23274-2</b> Hybrid- electric road vehicles-exhaust emissions and fuel consumption measurements – Part 2: Externally chargeable vehicles(under development to be assumed as guideline).	<b>ISO 23274</b> Hybrid-electric road vehicles exhaust emission and fuel consumption measurements non externally chargeable vehicle. (to be adapted for H2 use) <b>R101</b> (to be adapted).
	Maximum speed	-	<b>ISO</b> Technical Report (TR) FC Vehicles Maximum speed (being issued) <b>ISO 8715</b> Electric Road Vehicles-Road operating characteristics. <b>R68</b> -Amend .1 Uniform provisions concerning the approval of power-driven vehicles including pure electric vehicles with regards to the measurement of the maximum speed.		<b>R68</b> Uniform provisions concerning the approval of power-driven vehicles with regard to the measurements of the maximum speed

<b>Performance</b>	<b>Engine Power</b>	<b>IEC/CDV 62282-3-2</b> Stationary fuel cell power plants-test method for the performance	<b>R 85</b> Annex 6 Amend:2,8,4 Maximum power and maximum 30 min. power for Electric Vehicles	To be developed (as well as for ICE Hybrid electric)	To be developed (as well as for ICE Hybrid electric)
<b>Fuel quality (reference)</b>		<b>ISO 14687 (2008)</b> Hydrogen Fuel-Product specification	<b>ISO 14687</b>	<b>ISO 14687</b>	<b>ISO 14687</b>
<b>Terminology (reference)</b>		US Fuel Cell Council Fuel Cell Glossary <b>IEC/TC 62282-1 (2005)</b> Terminology	<b>ISO</b> Draft Technical Report(TR) on SC 21 Vocabulary <b>ISO 8713</b>		-

## References

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