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Fuel cell road vehicles — Energy consumption measurement — Vehicles fuelled with compressed hydrogen

Véhicules routiers avec pile à combustible — Mesurage de la consommation d'énergie — Véhicules alimentés par hydrogène comprimé

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 23828 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electrically propelled road vehicles*.

Introduction

Fuel cell vehicles (FCV) include the following types:

— pure fuel cell vehicle (PFCV), in which the fuel cell system is the only on-board energy source for propulsion and auxiliary systems;

— fuel cell hybrid electric vehicle (FCHEV), in which the fuel cell system is integrated with an on-board rechargeable energy storage system (RESS) for electric energy supply to propulsion and auxiliary systems.

FCHEV design options include:

a) externally chargeable or non-externally chargeable;

b) rechargeable energy storage system (RESS): battery or capacitor;

c) driver-selected operating modes: if the FCHEV has no driver-selected operating mode, it has only an FCHEV mode.

Table 1 shows the classification of FCHEV.

Table 1 — Classification of FCHEV

	Chargeability	Operating mode
FCHEV	externally chargeable	FCHEV mode
		EV mode
	non-externally chargeable	**FCHEV mode**
		EV mode

This International Standard is applicable to PFCV and to non-externally chargeable FCHEV with FCHEV mode only (see shaded boxes in Table 1).

Fuel cell road vehicles — Energy consumption measurement — Vehicles fuelled with compressed hydrogen

1 Scope

This International Standard specifies the procedures for measuring the energy consumption of fuel cell passenger cars and light duty trucks which use compressed hydrogen and which are not externally chargeable.

Annexes A, B and C describe procedures specific to particular regions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1176, *Road vehicle — Masses — Vocabulary and codes*

ISO 3833, *Road vehicles — Types — Terms and definitions*

ISO 10521-1, *Road vehicles — Road load — Part 1: Determination under reference atmospheric conditions*

ISO 10521-2, *Road vehicles — Road load — Part 2: Reproduction on chassis dynamometer*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3833 and ISO 1176 and the following apply.

3.1
battery state of charge
battery SOC
residual capacity of battery available to be discharged

NOTE Battery state of charge is normally expressed as a percentage of full charge.

3.2
charge balance of battery
change of charge in battery during test period

NOTE Charge balance of battery is normally expressed in A·h.

3.3
electric vehicle operation mode
EV operation mode
mode of a FCHEV in which only the RESS is used for the vehicle propulsion and possibly auxiliary systems

3.4
fuel cell hybrid electric vehicle operation mode
FCHEV operation mode
mode of a FCHEV in which both RESS and fuel cell system are used sequentially or simultaneously for vehicle propulsion

NOTE The fuel cell system can also charge the RESS during propulsion or standstill.

3.5
fuel cell vehicle
FCV
electric vehicle using a fuel cell power system for vehicle propulsion

NOTE A FCV can have additionally a RESS or other power sources for vehicle propulsion.

3.6
fuel cell hybrid electric vehicle
FCHEV
electric vehicle using a RESS and a fuel cell power system for vehicle propulsion

3.7
pure fuel cell vehicle
pure FCV
FCV using only a fuel cell power system for vehicle propulsion

3.8
rechargeable energy storage system
RESS
system that stores energy for delivery of electric energy and that is rechargeable

EXAMPLE Batteries, capacitors.

4 Measurement accuracy

4.1 General

Measurement accuracy shall be in accordance with national standards.

4.2 Hydrogen measurement accuracy

Test apparatus shall assure the accuracy of measurement of ± 1 % for the total mass of hydrogen consumption during the test cycle, unless otherwise specified in the relevant annexes.

5 Hydrogen consumption measurement

5.1 General

Various methods for the measurement of hydrogen consumption have been developed which reflect the current state of studies in the field. Hydrogen consumption shall be measured using one of the following:

— pressure method;

— gravimetric method;

— flow method.

These three methods, which are described in detail in Annexes D, E and F, have been shown to give sufficiently equivalent results. Other methods may also become applicable if they show comparable equivalence and reliability.

5.2 Pressure method

Hydrogen consumption is determined by measuring the pressure and temperature of gas in the high-pressure hydrogen tank, before and after the test. A tank with known internal volume that allows measurement of gas pressure and temperature shall be used for the test.

5.3 Gravimetric method

Hydrogen consumption is calculated by measuring the weight of the high-pressure hydrogen tank before and after the test. The tank used for the test shall be suitable for measuring weight.

5.4 Flow method

The amount of hydrogen supplied to and consumed by a vehicle is measured by a flow meter.

6 Test procedure

6.1 General condition

The test shall be conducted after preparation of the vehicle and test apparatus as described in this clause.

6.2 Vehicle condition

6.2.1 General

The vehicle shall be clean, and the windows and air entries that are not needed for the correct operation of the vehicle and the drive system shall be closed by the normal operating controls.

The lighting, signalling and auxiliary devices shall be turned off, except those required for testing and for usual day-time operation of the vehicle.

6.2.2 Vehicle stabilization

Prior to testing, the test vehicle shall be stabilized; this includes vehicle mileage accumulation in accordance with a manufacturer-determined distance, unless otherwise specified in Annex A, B or C (as appropriate).

6.2.3 Vehicle appendages

Vehicles shall be tested with normal appendages (mirrors, bumpers, etc.). Where necessary, certain items (e.g. hub caps) may be removed for safety on the dynamometer.

6.2.4 Vehicle test mass

The vehicle test mass shall be selected in accordance with Annex A, B, or C.

6.2.5 Tyres

6.2.5.1 General

Tyres recommended by the vehicle manufacturer shall be used.

6.2.5.2 Tyre pressure

When the vehicle tyres are at ambient temperature, they shall be inflated to the pressure specified by the vehicle manufacturer for the chosen test (track or chassis dynamometer).

6.2.5.3 Tyre conditioning

Tyres shall be conditioned as recommended by the vehicle manufacturer. See Annex A, B, or C for additional requirements.

6.2.6 Lubricants

The vehicle lubricants specified by the manufacturer shall be used.

6.2.7 Gear shifting

If the vehicle is fitted with a manually shifted gear box, gear shifting positions shall correspond to the test procedures described in Annexes A, B and C. However, the shift positions may be selected and determined previously in accordance with the vehicle characteristics.

6.2.8 Regenerative braking

If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all dynamometer testing. If a vehicle is equipped with an antilock braking system (ABS) or a traction control system (TCS) and is tested on a single-roll dynamometer, these systems may inadvertently interpret the non-movement of the set of wheels that are off the dynamometer as a malfunctioning system. If so, modifications to these systems shall be made to achieve normal operation of the remaining vehicle systems, including the regenerative braking system.

6.2.9 RESS stabilization

The RESS shall have been stabilized with the vehicle, as defined in 6.2.2, or by equivalent conditioning.

6.3 Chassis dynamometer conditions

6.3.1 General

The vehicle generally should be tested on a single-roll chassis dynamometer. A four-wheel-drive vehicle shall be tested by modifying the drive train of the vehicle. When the vehicle is modified, the details shall be explained in the test report.

A four-wheel-drive dynamometer test may be performed when a modification for a single-roll dynamometer test is not possible for a specific four-wheel-drive vehicle.

6.3.2 Dynamometer calibration

The dynamometer shall be calibrated as specified by the vehicle manufacturer, or in accordance with the specifications indicated in the service manual provided by the dynamometer manufacturer.

6.3.3 Dynamometer warm-up

The dynamometer shall be warmed up sufficiently prior to the testing.

6.3.4 Determining the dynamometer load coefficient

The determination of vehicle road load under reference atmospheric conditions shall conform to ISO 10521-1, and the reproduction on a chassis dynamometer shall conform to ISO 10521-2 or national standards. Vehicles equipped with regenerative braking systems that are activated at least in part when the brake pedal is not depressed shall have regenerative braking disabled during the deceleration portion of coast-down testing on both the test track and dynamometer.

6.4 Fuel consumption tests

6.4.1 General

Depending on the region concerned, the appropriate procedure shall be followed from Annex A, B, or C. Details and common procedures for each test mode are described below.

6.4.2 Vehicle preconditioning

Vehicle preconditioning shall be carried out in accordance with the annex appropriate for the region. In the case of FCHEV, the RESS state of charge may be pre-adjusted by charging or discharging, to obtain a suitable energy difference in RESS between the start and the end of test.

6.4.3 Vehicle soak

The vehicle shall be soaked in accordance with the appropriate regional procedure prescribed in Annex A, B, or C.

6.5 Measurement over scheduled driving test

For the measurement of hydrogen consumption, the test vehicle shall be driven on the chassis dynamometer in accordance with the running mode prescribed for the region (see Annex A, B, or C, as appropriate). The hydrogen consumption can be measured by one of the methods described in Annex D, E, or F, or by an alternative method that provides equivalent accuracy.

The hydrogen consumption is determined by means of one of the following equations:

$$C_{F1} = \frac{b_{t0} \times 10^{-3}}{L} = \frac{w \times \frac{22{,}414}{m} \times 10^{-3}}{L} \quad (1)$$

$$C_{F2} = \frac{w \times 10^{-3}}{L} = \frac{b_{t0} \times \frac{m}{22{,}414} \times 10^{-3}}{L} \quad (2)$$

$$C_{F3} = \frac{b_{t0} \times 10^{-3} \times Q_H}{L} = \frac{w \times \frac{22{,}414}{m} \times 10^{-3} \times Q_H}{L} \quad (3)$$

where

C_{F1} is the hydrogen consumption per unit distance, in m^3/km, referred to volume at normal conditions (273 K; 101,3 kPa);

C_{F2} is the hydrogen consumption per unit distance, in kg/km, referred to weight;

C_{F3} is the hydrogen consumption per unit distance, in MJ/km, referred to caloric value;

L is the distance, in km;

b_{t0} is the hydrogen consumption at normal conditions (273 K, 101,3 kPa);

w is the hydrogen consumption, in g;

m is the molecular weight of hydrogen (2,016);

Q_H is the lower calorific value of hydrogen (10,8 MJ/Nm^3).

6.6 Correction of the test results for FCHEV

6.6.1 General

After the FCHEV has been tested, the hydrogen consumption shall be corrected if the energy difference in the RESS between the start and the end of test is above the limit described in 6.6.2.

6.6.2 Allowable limit for RESS energy change for FCHEV

The allowable limit for RESS energy change is

$$| \Delta E_{RESS} | \leqslant 0{,}01 \times E_{CF} \quad (4)$$

where

ΔE_{RESS} is the energy change in RESS over the test cycle;

E_{CF} is the energy of consumed fuel over the test cycle.

Further details are described in Annex J.

6.6.3 Correction procedure using a correction coefficient

The hydrogen consumption at $\Delta E_{RESS} = 0$ shall be calculated by using a correction coefficient to be provided by the vehicle manufacturer. Details on the acquisition and the application of the correction coefficient are given in Annex K.

NOTE Annex L gives recommendations on the data collecting procedure to obtain the correction coefficient.

7 Presentation of results

Test results should be recorded in accordance with Annex I. The fourth significant digit should be rounded off to provide the hydrogen consumption rate to three significant digits.

Other data should be recorded as required by the regional regulations.

Annex A
(informative)

Test procedure in Japan

A.1 General

This annex describes the typical procedures and related conditions in Japan for measuring the fuel consumption of passenger cars and light duty trucks, as defined in Japanese regulations.

A.2 Accuracy for determining vehicle road load and others

When determining road load, the accuracy shall conform to ISO 10521-1 and ISO 10521-2.

A.3 Driving procedure

A.3.1 General

The gear manipulation in each operational condition specified in Tables A.1 and A.2 shall be performed smoothly and quickly in accordance with the instructions in this clause.

A.3.2 Vehicles with manual transmission

A.3.2.1 The idling operation refers to a condition in which the accelerator pedal is not depressed, with the transmission gear in neutral.

A.3.2.2 The transmission gear shall be shifted to the low gear position (or such a gear in instances where the “low” gear position should read otherwise in Tables A.1 and A.2) 5 s before the idling operation mode is switched to the acceleration mode.

A.3.2.3 For deceleration, the clutch shall be disengaged at a speed of 10 km/h during the deceleration operation from 20 km/h to 0 km/h, and at a speed of 20 km/h during the deceleration operation from 40 km/h to 0 km/h, as specified in Tables A.1 and A.2. In the same way, the clutch shall be disengaged at a speed of 30 km/h during the deceleration operation from 70 km/h to 0 km/h, as specified in Table A.2.

A.3.2.4 On vehicles with a 6-speed transmission in which it is not possible to drive by operating the shift lever in respective gear positions as specified in Table A.2 because of the running performance of the vehicle, driving may be carried out in accordance with the example of the 5-speed transmission specified in Table A.2.

A.3.2.5 If the revolutions of the motor of the test vehicle exceed the revolution speed at which the motor delivers its maximum output during the operation of the test vehicle, the gear position that is one step higher than the original gear may be used. In this case, the vehicle speed at which the gearshift takes place shall be the vehicle speed corresponding to the revolution speed at which the motor delivers its maximum output.

A.3.3 Vehicle with automatic transmission

The selector position shall remain in drive position. No further manipulation shall be made.