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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 committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 21, *Electrically propelled road vehicles*.

This second edition cancels and replaces the first edition (ISO 23828:2008), which has been technically revised.

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 that use compressed hydrogen and which are not externally chargeable.

2 Normative references

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

ISO 10521 (all parts), *Road vehicles — Road load*

ISO 14687-2, *Hydrogen fuel — Product specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles*

ISO/TR 8713, *Electrically propelled road vehicles — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 8713 and the following apply.

3.1
applicable driving test
ADT
single driving test schedule which is specified for each region

EXAMPLE Chassis dynamometer test cycle for light-duty vehicles in Japan (JC08), New European Driving Cycle (NEDC), Urban Dynamometer Driving Schedule (UDDS).

3.2
charge balance of battery
change of charge in battery during fuel consumption measurement

Note 1 to entry: Normally expressed in Ah.

3.3
energy balance of battery
ΔE_{RESS}
change of energy in battery during fuel consumption measurement

Note 1 to entry: Normally expressed in Wh.

Note 2 to entry: For practical use, the energy balance of a rechargeable energy storage system (RESS) is approximated by multiplying the charge balance of battery in Ah by the nominal voltage in V. “Nominal voltage” is defined in ISO 12405-1 or ISO 12405-2.

3.4
fuel cell hybrid electric vehicle
FCHEV
electrically propelled vehicle with a RESS and a fuel cell system as power sources for vehicle propulsion

3.5
fuel cell vehicle
FCV
electrically propelled vehicle with a fuel cell system as power source for vehicle propulsion

3.6
pure fuel cell vehicle
pure FCV
FCV with only a fuel cell system as power source for vehicle propulsion

3.7
rated capacity
supplier's specification of the total number of ampere-hours that can be withdrawn from a fully charged battery pack or system for a specified set of test conditions such as discharge rate, temperature, discharge cut-off voltage, etc.

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

EXAMPLE Batteries, capacitors.

3.9
regenerative braking
braking with conversion of kinetic energy into electric energy for charging the RESS

3.10
state of charge
SOC
available capacity in a battery pack or system expressed as a percentage of rated capacity

4 Measurement accuracy

4.1 General

Measurement accuracy shall be in accordance with national standards.

4.2 Hydrogen measurement accuracy

Test apparatus shall ensure the accuracy of measurement of ±1 % for the total mass of hydrogen consumption during the applicable driving test (ADT), unless otherwise specified in the relevant annexes.

5 Hydrogen consumption measurement

5.1 General

Hydrogen consumption shall be measured using one of the following:

— pressure method;

— gravimetric method;

— flow method.

5.2 Pressure method

Hydrogen consumption is determined by measuring the pressure and temperature of gas in the 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. Pressure method shall be performed in accordance with Annex D.

5.3 Gravimetric method

Hydrogen consumption is calculated by measuring the mass of the hydrogen tank before and after the test. Gravimetric method shall be performed in accordance with Annex E.

5.4 Flow method

The amount of hydrogen supplied to a vehicle is measured by a flowmeter. Flow method shall be performed in accordance with Annex F.

6 Test conditions and instrumentation

6.1 Test conditions

6.1.1 General

For test conditions, the following applies unless otherwise specified in the regional standards or regulations (see Annex A, B, or C, for example).

6.1.2 Ambient temperature

Tests shall be conducted at an ambient temperature of (25 ± 5) °C.

6.1.3 Vehicle conditions

6.1.3.1 Vehicle conditioning

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.

6.1.3.2 Vehicle appendages

Vehicles shall be tested with normal appendages (mirrors, bumpers, etc.). When the vehicle is on the dynamometer, certain items (e.g. hub caps) should be removed for reasons of safety, where necessary.

6.1.3.3 Vehicle test mass

The vehicle test mass shall be selected according to the regional standards and/or regulations (see Annex A, B, or C, for example).

6.1.3.4 Tyres

6.1.3.4.1 General

The correctly rated tyres as recommended by the vehicle manufacturer shall be used.

6.1.3.4.2 Tyre pressure

The vehicle tyres shall be inflated to the pressure specified by the vehicle manufacturer according to the test chosen (track or chassis dynamometer).

6.1.3.4.3 Tyre conditioning

The tyres shall be conditioned as recommended by the vehicle manufacturer.

6.1.3.5 Lubricants

The vehicle lubricants normally specified by the manufacturer shall be used.

6.1.3.6 Gear shifting

If the vehicle is fitted with a manually shifted gear box, gear shifting positions shall correspond to the regional test procedure (see Annex A, B, or C, for example). However, the shift positions should be selected and determined in accordance with the vehicle manufacturer's specification.

6.1.3.7 Regenerative braking

If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all dynamometer testing except where specified in 6.1.4.4 chassis dynamometer conditions.

If the vehicle is tested on a single axle dynamometer and is equipped with systems such as an antilock braking system (ABS) or a traction control system (TCS), those systems can inadvertently interpret the non-movement of the set of wheels that are off the dynamometer as a malfunctioning system. If so, these systems shall be temporally disabled for adjustment to achieve normal operation of the remaining vehicle systems, including the regenerative braking system.

6.1.3.8 RESS conditioning

The RESS shall be conditioned with the vehicle as specified in 6.1.3.1 or by equivalent conditioning.

6.1.3.9 Test fuel

ISO 14687-2 and the equivalent regional standards shall apply to test fuel.

6.1.4 Chassis dynamometer conditions

6.1.4.1 General

The vehicle should generally be tested on a single-axle chassis dynamometer. A vehicle with four-wheel drive 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.

Double-axle chassis dynamometer testing should be performed if a modification for single-axle chassis dynamometer testing is not possible for a specific four-wheel drive vehicle.

6.1.4.2 Dynamometer calibration

The dynamometer shall be calibrated in accordance with the specifications indicated in the service manual provided by the dynamometer manufacturers.

6.1.4.3 Dynamometer warm-up

The dynamometer shall be warmed up sufficiently prior to testing.

6.1.4.4 Determining the dynamometer load coefficient

The determination of vehicle road load and the reproduction on a chassis dynamometer shall conform to ISO 10521. 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.

6.2 Test instrumentation

Test instrumentation shall have accuracy levels as shown in Table 1, unless specified differently in Annex A, B, or C.

Table 1 — Accuracy of measured values

Item	Unit	Accuracy
Time	s	±0,1 s
Distance	m	±0,1 %
Temperature	°C	±1 °C
Speed	km/h	±1 %
Mass	kg	±0,5 %
Current	A	±0,5 %
Capacitor voltage	V	±0,5 % of nominal voltage

6.3 Fuel consumption tests

6.3.1 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.

6.3.2 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 can be pre-adjusted by charging or discharging, to obtain a suitable energy difference in RESS between the start and the end of test.

6.3.3 Vehicle soak

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

6.3.4 Vehicle movement to the test room

When the vehicle is brought into the test room, and moved during the test if necessary, it shall be pushed or towed (neither driven nor regenerative recharged). The test vehicle shall be set on the chassis dynamometer after the chassis dynamometer has warmed up just before the test. The vehicle shall not be activated during soak until right before starting the test.

6.4 Measurement and calculation over applicable driving test (ADT)

For the measurement of hydrogen consumption, the test vehicle shall be driven on the chassis dynamometer in accordance with the ADT prescribed for the region (see Annex A, B, or C). The hydrogen consumption shall 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 per unit distance is determined by means of one of the following formulae:

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

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

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

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 mass;

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 in l (273 K, 101,3 kPa);

w is the hydrogen consumption, in g;

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

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

6.5 Correction of the test results for FCHEV

6.5.1 General

Measured hydrogen consumption shall be corrected if these test results are influenced by RESS energy balance during the test. However, the correction is not necessary if the RESS energy balance satisfies the conditions in 6.5.2.

6.5.2 Allowable range of RESS energy balance

The correction of the test results is not necessary for the following range of the RESS energy balance:

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

where

ΔE_{RESS} is the energy change in RESS over the ADT;

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

ΔE_{RESS} shall be calculated in accordance with Annex J.

6.5.3 Correction procedure by correction coefficient

The vehicle manufacturer shall deliver the correction coefficient to calculate the fuel consumption at $\Delta E_{RESS} = 0$. The correction coefficient can be obtained in accordance with Annex K. When the measured value is independent of ΔE_{RESS}, a correction is not required.

7 Presentation of results

Test results should be recorded in accordance with the regional regulations. See Annex I for example.

Annex A
(informative)

Test procedure in Japan

A.1 General

Annex A describes the procedures and related conditions in Japan (JC08-mode) to measure the fuel consumption of the passenger cars and light-duty trucks defined in Japan regulations.

Japan Regulations are written as “Announcement that Prescribes Details of Safety Regulations for Road Vehicles (Ministry of Land, Infrastructure, Transport and Tourism [MLIT] Announcement No. 619, 2002;) Attachment 42”, “TRIAS 99-006”, and “TRIAS 31-J042(3)”.

A.2 Test

A.2.1 Chassis dynamometer

The equivalent inertia mass of the chassis dynamometer shall be set to the standard value of equivalent inertia mass specified in the right column of Table A.1 according to the relative test vehicle mass (vehicle curb mass plus 110 kg) specified in the left column of the table. Furthermore, if the standard value of the equivalent inertia mass in the right column of the table cannot be set, it is permissible to set the equivalent inertia mass within a range between the said standard value and the said standard value plus 10 %.

A.2.2 Applicable driving test (ADT)

The test vehicle shall run the applicable driving test (ADT). In Japan, JC08-mode driving schedule [0s to 1204s] specified in Japan Regulations is applicable (see Figure A.1).

A.2.3 Test vehicle mass

Test vehicle mass at measuring running resistance and at measuring fuel consumption on the chassis dynamometer shall be vehicle curb mass plus 110 kg.

A.3 Test procedure

A.3.1 General

Preconditioning shall be performed on the chassis dynamometer after given road load setting. Then, the test procedure shall be carried out according to the test flow in Figure A.2 or A.3.

A.3.2 Cold start JC08 mode (JC08CM)

In the case of cold start, the test starts immediately after the specified soak procedure (see A.1). Test flow in Figure A.2 is applicable.

A.3.3 Hot start JC08 mode (JC08HM)

In the case of hot start, the vehicle is under warmed-up condition. Test flow in Figure A.3 is applicable.

A.4 Calculation of fuel consumption test procedure

The measured hydrogen consumption shall be calculated to the required unit value. See 6.4.

Table A.1 — Test vehicle mass and standard value of equivalent inertia mass

Test vehicle mass (kg)	**Standard value of equivalent inertia mass** (kg)
~ 480	455
481 ~ 540	510
541 ~ 595	570
596 ~ 650	625
651 ~ 710	680
711 ~ 765	740
766 ~ 850	800
851 ~ 965	910
966 ~ 1 080	1 020
1 081 ~ 1 190	1 130
1 191 ~ 1 305	1 250
1 306 ~ 1 420	1 360
1 421 ~ 1 530	1 470
1 531 ~ 1 640	1 590
1 641 ~ 1 760	1 700
1 761 ~ 1 870	1 810
1 871 ~ 1 980	1 930
1 981 ~ 2 100	2 040
2 101 ~ 2 210	2 150
2 211 ~ 2 380	2 270
2 381 ~ 2 625	2 500
2 626 ~ 2 875	2 750
2 876 ~ 3 250	3 000
3 251 ~ 3 750	3 500
Continued in increments of 500 kg	Continued in increments of 500 kg