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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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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

This third edition cancels and replaces the second edition (ISO 23828:2013), which has been technically revised.

The main changes are as follows:

— deletion of Annexes A, B and C (regional tests) because their information is obsolete;

— harmonization of terms and definitions with ISO/TR 8713 and ISO 23274-1;

— addition of a method to correct the hydrogen amount in the external hydrogen supplying line;

— integration of externally chargeable FCHEV;

— calculation of driving range;

— calculation of contribution of RESS and hydrogen fuel for the driving range.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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

1 Scope

This document specifies the procedures for measuring the energy consumption and driving range of fuel cell passenger cars and light-duty trucks that use compressed hydrogen.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 10521 (all parts), *Road vehicles — Road load*

ISO 14687, *Hydrogen fuel quality — Product specification*

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.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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

Note 1 to entry: Chassis dynamometer test schedules for a relevant region are the Worldwide Light-duty Test Cycle (WLTC) or the Urban Dynamometer Driving Schedule (UDDS), for example.

3.2
charge balance of RESS
change of charge in the *rechargeable energy storage system (RESS)* (3.13) during an *applicable driving test (ADT)* (3.1)

Note 1 to entry: Normally expressed in ampere hours (Ah).

3.3
charge-depleting state
CD state
operating mode of an HEV in which the vehicle runs by consuming the stored electric energy in the *rechargeable energy storage system (RESS)* (3.13) from an external electric power source or along with the fuel energy simultaneously or sequentially until *CS state* (3.4)

3.4
charge-sustaining state
CS state
operating mode where the HEV runs by consuming the fuel energy while sustaining the electric energy of the *rechargeable energy storage system (RESS)* (3.13)

3.5
energy balance of RESS
ΔE_{RESS}
change of *rechargeable energy storage system (RESS)* (3.13) energy state during an *applicable driving test (ADT)* (3.1)

Note 1 to entry: Normally expressed in watt hours (Wh).

Note 2 to entry: For practical use, the energy balance of the RESS is approximated by multiplying the *charge balance of RESS* (3.2) in ampere hours (Ah) with the nominal voltage of the RESS in volts (V).

3.6
externally chargeable FCHEV
externally chargeable fuel cell hybrid electric vehicle
fuel cell hybrid electric vehicle (FCHEV) (3.7) with a *rechargeable energy storage system (RESS)* (3.13) that is intended to be charged from an external electric energy source

Note 1 to entry: External charge for conditioning of the RESS is not included.

3.7
fuel cell hybrid electric vehicle
FCHEV
electrically propelled vehicle with a *rechargeable energy storage system (RESS)* (3.13) and a fuel cell system as power sources for vehicle propulsion

3.8
fuel cell vehicle
FCV
electrically propelled vehicle with a fuel cell system as the power source for vehicle propulsion

Note 1 to entry: An FCV may also have a *rechargeable energy storage system (RESS)* (3.13) or another power source for vehicle propulsion.

3.9
state of charge of hydrogen
density (or mass) ratio of hydrogen in the original hydrogen tank between the original hydrogen tank condition and the capacity at *nominal working pressure (NWP)* (3.11) when the system is equilibrated at 15 °C

Note 1 to entry: State of charge of hydrogen is expressed as a percentage and is computed based on the gas density according to formula below.

Note 2 to entry: The accuracy of the NIST formula has been quantified to be to within 0,01 % from 255 K to 1 000 K with pressures to 120 MPa at the time of publication of this document.

Note 3 to entry: (%) can be calculated as follows:

$$\frac{\rho_1}{\rho_2} \times 100$$

where

ρ_1 is the density of hydrogen under the specific gas conditions;

ρ_2 is the density of hydrogen at the nominal working pressure at a gas temperature of 15 °C.

The hydrogen densities at the two major nominal working pressures are:

— density of H_2 at 35 MPa and 15 °C = 24,0 g/l,

— density of H_2 at 70 MPa and 15 °C = 40,2 g/l.

Note 4 to entry: The ρ_1 function for hydrogen is available from the National Institute of Standards and Technology (NIST) at https://nvlpubs.nist.gov/nistpubs/jres/113/6/V113.N06.A05.pdf.

[SOURCE: ISO 19880-1:2020, 3.78, modified — The term was originally "state of charge" and "compressed hydrogen storage system (CHSS)" has been replaced by "original hydrogen tank".]

3.10
non-externally chargeable FCHEV
non-externally chargeable fuel cell hybrid electric vehicle
fuel cell hybrid electric vehicle (FCHEV) (3.7) with a *rechargeable energy storage system (RESS)* (3.13) that is not intended to be charged from an external electric energy source

3.11
nominal working pressure
NWP
container pressure, as specified by the container manufacturer, at a uniform gas temperature of 15 °C and full gas content

3.12
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.

3.13
rechargeable energy storage system
RESS
rechargeable system that stores energy for delivery of electric energy for the electric drive

EXAMPLE Batteries or capacitors.

3.14
regenerative braking
braking with conversion of kinetic energy into electric energy for charging the *rechargeable energy storage system (RESS)* (3.13)

3.15
state of charge
SOC
available capacity of a *rechargeable energy storage system (RESS)* (3.13)or RESS subsystem expressed as a percentage of *rated capacity* (3.12)

4 Symbols and abbreviated terms

ADT	applicable driving test
CD	charge-depleting
CS	charge-sustaining
E	energy
E_{CH2}	energy of consumed hydrogen

ECU	electronic control unit
E_{RESS}	energy of RESS
FCHEV	fuel cell hybrid electric vehicle
FCV	fuel cell vehicle
HEV	hybrid-electric vehicle
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
NWP	nominal working pressure
RESS	rechargeable energy storage system
SOC	state of charge
UDDS	Urban Dynamometer Driving Schedule
WLTC	Worldwide Light-duty Test Cycle

5 Hydrogen measurement accuracy

The hydrogen measurement device shall ensure an accuracy of ±1 % for the total mass of hydrogen consumption during the ADT, unless otherwise specified in the relevant regional ADT standard.

6 Hydrogen consumption measurement

6.1 General

Hydrogen consumption shall be measured using one of the following methods:

— pressure method (see Annex A);

— gravimetric method (see Annex B);

— flow method (see Annex C).

NOTE The current method (see Annex D) can be used.

6.2 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 A.

6.3 Gravimetric method

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

6.4 Flow method

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

7 Fuel consumption test

7.1 Test conditions

7.1.1 General

For test conditions, the following applies unless otherwise specified in the relevant regional ADT standard.

7.1.2 Ambient temperature

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

7.1.3 Vehicle conditions

7.1.3.1 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 the relevant regional ADT standard.

7.1.3.2 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.

7.1.3.3 Vehicle test mass

The vehicle test mass shall be selected according to the relevant regional ADT standard.

7.1.3.4 Tyres

7.1.3.4.1 General

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

7.1.3.4.2 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).

7.1.3.4.3 Tyre conditioning

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

7.1.3.5 Lubricants

The lubricants specified by the vehicle manufacturer shall be used.

7.1.3.6 Gear shifting

If the vehicle is fitted with a manually shifted gear box, the gear shifting positions should be selected and determined in accordance with the vehicle manufacturer's specification.

NOTE The shift positions can be referred to the relevant regional ADT procedure.

7.1.3.7 Regenerative braking

If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all dynamometer testing except where specified in 7.1.4.4 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.

7.1.3.8 RESS conditioning

The RESS shall be conditioned with the vehicle as specified in 7.1.3.1 or by equivalent conditioning.

7.1.3.9 Test fuel

ISO 14687 or the equivalent regional standard shall apply to the test fuel.

7.1.4 Chassis dynamometer conditions

7.1.4.1 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.

7.1.4.2 Dynamometer calibration

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

7.1.4.3 Dynamometer warm-up

The dynamometer shall be warmed up sufficiently prior to testing.

7.1.4.4 Determining the dynamometer load coefficient

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

7.2 Test instrumentation

The test instrumentation shall have the accuracy levels as given in Table 1, unless otherwise specified in the relevant regional ADT standard.

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 %
AC electric energy	Wh	±0,5 %
DC electric energy	Wh	±0,3 % [a]
DC current	A	±0,3 % [a]
DC voltage	V	±0,3 % [a]

[a] Any errors in the DC electric energy measurement system shall be less than 1 % of the reading or 0,3 % of full scale. (Pulsed power electronics measurement needs wide dynamic range even if small power.)

For the DC current measurement without direct voltage sensing, wideband ampere-hour meter or wideband meter is required.

The wideband meter (power analyser) is an instrument for processing power and energy in pulsed power electronics by current and voltage inputs. Its bandwidth shall be at least ten times as high as the switching frequency of the pulsed power electronics, and update period of its outputs shall be 0,05 s or less to get enough time resolution.

Voltage probes and current sensors shall be installed in such a way as to measure voltage at RESS and FC terminals, and all current leaving and entering the RESS and leaving the FC.

The electronic control unit (ECU) shall be alternatively applied, if the accuracy of ECU data certifies corresponding accuracy in Table 1.

NOTE If the ECU of the test vehicle has not enough accuracy, the accuracy of the data through the ECU appears on the data sheet. The accuracy of resultant specific energy consumption and range can be estimated and they are also on the data sheet.

7.3 Charging of the RESS of externally chargeable FCHEV

7.3.1 Application of a normal charge

7.3.1.1 Normal charging procedure

The charging of the RESS shall be carried out at an ambient temperature of (25 ± 5) °C. The normal charging procedure shall be in accordance with the vehicle manufacturer's specification for normal operation.

For the normal charging procedure all types of special charging shall be excluded, for example, RESS service charging.

7.3.1.2 End-of-charge criteria

The end-of-charge criteria shall correspond to a charging time of 12 h except if a clear indication is given to the driver by the standard instrumentation that the RESS is not yet fully charged. In this case, the maximum charging time shall be in accordance with the manufacturer's specification. After charging, the vehicle shall not be conductively connected to an external electric power source unless otherwise specified by the manufacturer.