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

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National foreword

This British Standard is the UK implementation of ISO 23828:2013. It supersedes BS ISO 23828:2008 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/69, Electric vehicles.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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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 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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

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
$\Delta \boldsymbol{E}_{RESS}$
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)

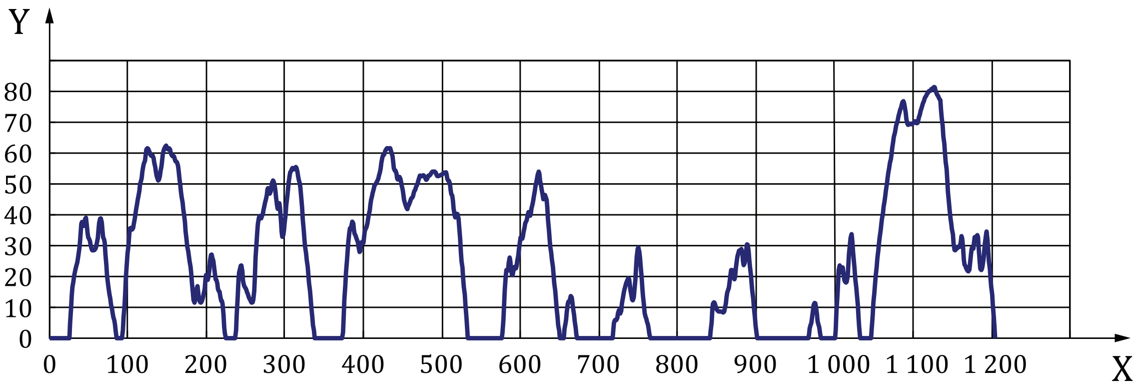
In the case of hot start, the vehicle is under warmed-up condition. Test flow in Figure A.3 is applicable.

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



Key

X time, s

Y vehicle speed, km/h

Figure A.1 — JC08-mode driving schedule

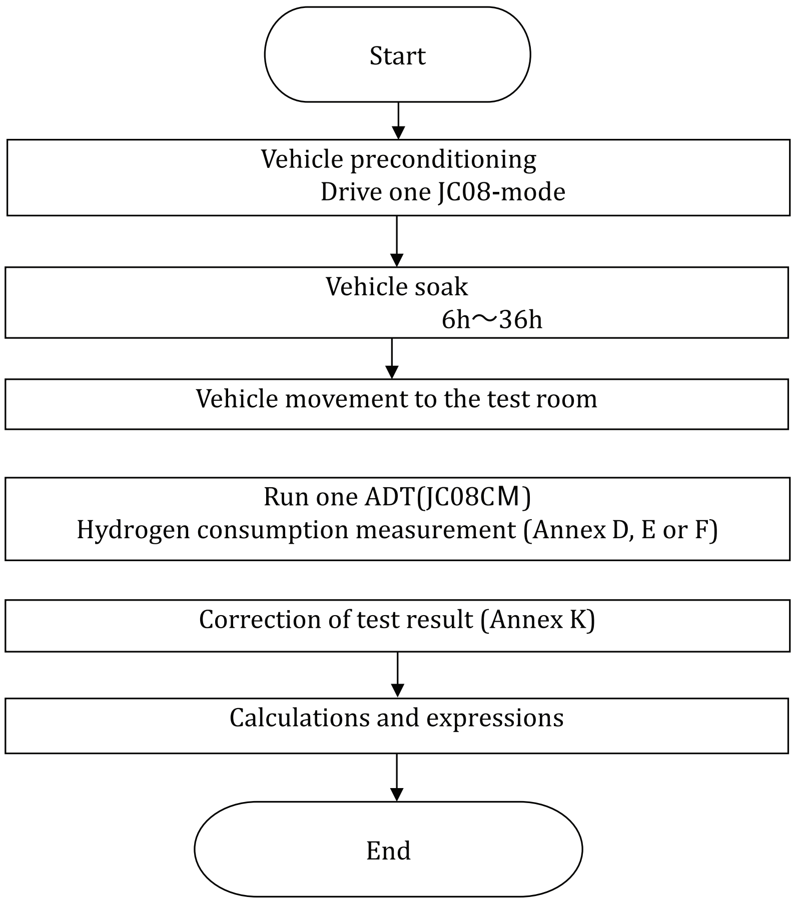


Figure A.2 — JC08CM test flow

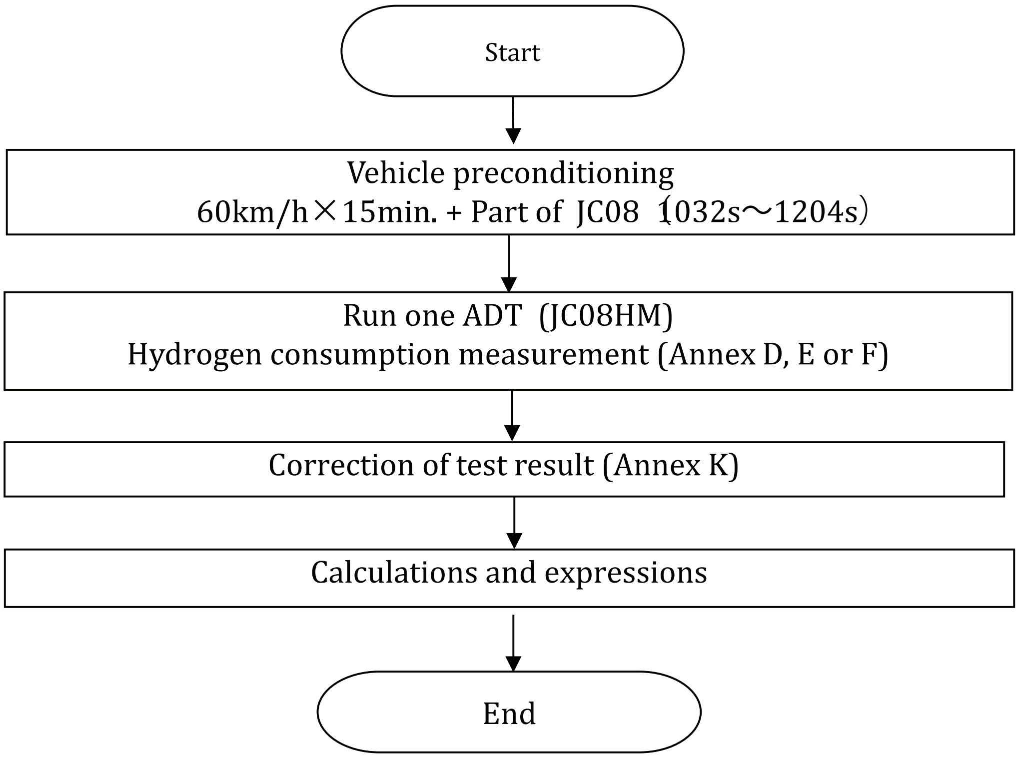


Figure A.3 — JC08HM test flow

Annex B
(informative)

Test procedure in Europe

B.1 General

Based on the legal requirements in Europe, Annex B specifies the specific preconditioning procedures and relevant test equipment for the determination of hydrogen consumption of pure FCV and FCHEV non-externally chargeable and with FCHEV mode only of categories M1 and N1 with a maximum permissible total mass (in accordance with ISO 1176) of 3 500 kg.

NOTE 1 The outline given in Annex B contains only those elements essential to understanding the procedure. For further details, reference is made to the relevant clauses and subclauses in the regulations UNECE R 101 and UNECE R 83.

NOTE 2 Annex B is based on the following editions of the two regulations:

- UNECE R 101: Trans/WP.29/GRPE/2004/2, 30 October 2003;

- UNECE R 83: E/ECE/324 Rev.1/Add.82/Rev.2 E/ECE/Trans/505, 30 October 2001.

It does not necessarily reflect subsequent amendments to UNECE R 101 and UNECE R 83.

B.2 Test equipment

B.2.1 Chassis dynamometer

Features, accuracy, load and inertia setting, calibration, and other steps to prepare the chassis dynamometer to be used are prescribed in UNECE R 83, Annex 4, 4.1, 5.1, and 5.2 and in Appendices 2 and 3 of Annex 4. The adjustment of the inertia simulators to the vehicle's translatory inertias shall be in accordance with Table B.1 (as given in UNECE R 83, Annex 4, 5.1).

Table B.1 — Equivalent inertia of the dynamometer related to the reference mass of the vehicle

Reference mass of the vehicle RW (kg)	**Equivalent inertia** (kg)
RW ≤ 480	455
480 < RW ≤ 540	510
540 < RW ≤ 595	570
595 < RW ≤ 650	625
650 < RW ≤ 710	680
710 < RW ≤ 765	740
765 < RW ≤ 850	800
850 < RW ≤ 965	910
965 < RW ≤ 1 080	1 020
1 080 < RW ≤ 1 190	1 130
1 190 < RW ≤ 1 305	1 250
1 305 < RW ≤ 1 420	1 360
1 420 < RW ≤ 1 530	1 470

Table B.1 *(continued)*

Reference mass of the vehicle RW (kg)	**Equivalent inertia** (kg)
1 530 < RW ≤ 1 640	1 590
1 640 < RW ≤ 1 760	1 700
1 760 < RW ≤ 1 870	1 810
1 870 < RW ≤ 1 980	1 930
1 980 < RW ≤ 2 100	2 040
2 100 < RW ≤ 2 210	2 150
2 210 < RW ≤ 2 380	2 270
2 380 < RW ≤ 2 610	2 270
2 610 < RW	2 270

B.2.2 Test equipment for hydrogen measurement methods

For specific test equipment for the hydrogen measurement methods, see Clause 5 and Annexes D, E, and F.

B.3 Test vehicle

B.3.1 General

The test vehicle shall be in running order, as determined by the manufacturer, with all the equipment provided as standard.

B.3.2 Test mass

The mass of the vehicle under test (referred to as "reference mass" in UNECE R 83, 2.2) shall be the "unloaded mass" plus a uniform figure of 100 kg. The "unloaded mass" (see UNECE R 83, 2.2.1) is the mass of the vehicle in running order, without load and persons, but with the hydrogen tank 90 % full.

B.3.3 Tyres

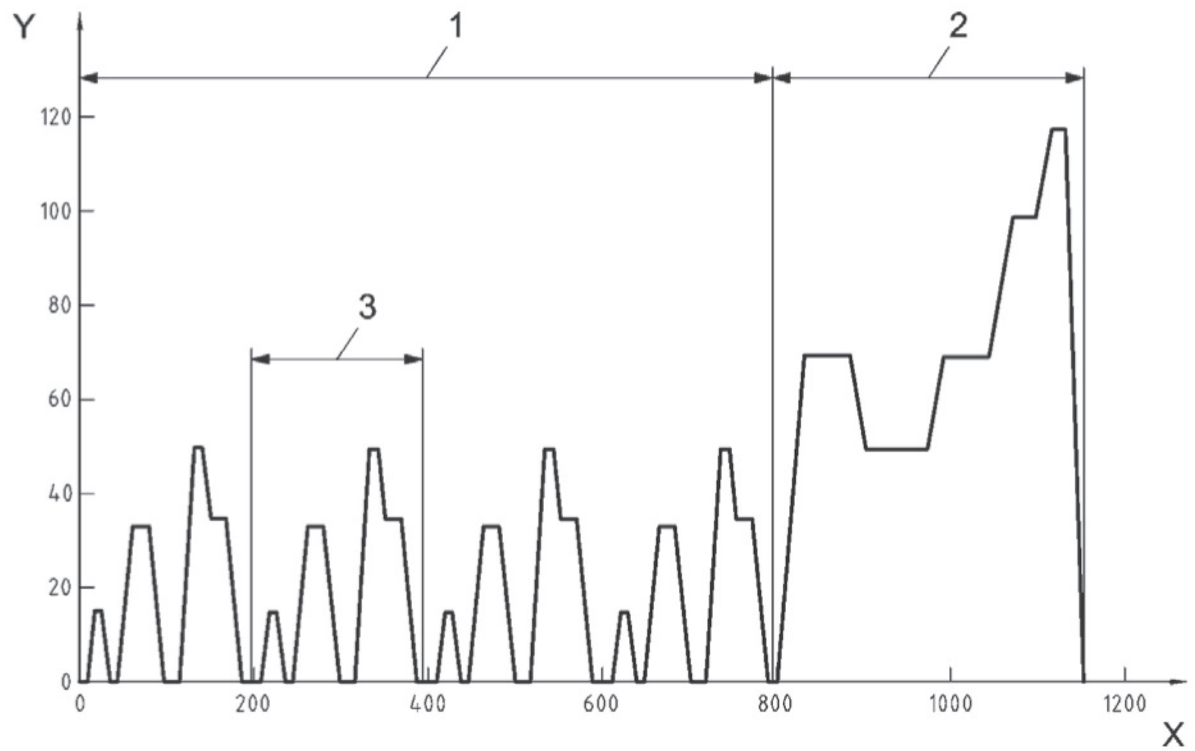
The tests shall be performed with standard width tyres, as provided by the vehicle manufacturer. Alternatively, the prescription of UNECE R 83, Annex 4, Appendix 3, 4.1.2, can be applied, i.e. only the widest of the standard widths or the widest minus one (in case of more than three standard widths) shall be chosen.

The tyre pressure shall comply with the vehicle manufacturer specification, but can be increased by up to 50 % when the test is carried out on a two-roller dynamometer (see UNECE R 83, Annex 4, 5.3.2).

B.4 Test cycle

The test cycle to be applied shall be the same as that prescribed for the Type I test. This test, including allowable tolerances, is described in UNECE R 83, Annex 4, Appendix 1.

The test cycle is made up of one Part 1 (urban) cycle, consisting of four elementary urban cycles, and one Part 2 (extra-urban) cycle, as illustrated roughly in Figure B.1 and described in Table B.2.



Key

X time, s

Y vehicle speed, km/h

1 part 1, urban cycle

2 part 2, extra-urban cycle

3 elementary urban cycle

Figure B.1 — Test cycle

Table B.2 — General information on the test cycle

	Urban cycle	Extra-urban cycle
Average speed	19 km/h	62,6 km/h
Max. speed	50 km/h	120 km/h
Effective running time	4 × 195 s = 780 s (13 min)	400 s (6 min, 40 s)

B.5 Test procedure

B.5.1 Preconditioning of the vehicle

The vehicle shall be stabilized in accordance with the vehicle manufacturer's specification, followed by two consecutive full test cycles (see B.4).

B.5.2 Conditioning of the vehicle

After preconditioning in accordance with B.5.1, the vehicle shall be kept in a room with a relative constant temperature of between 20 °C and 30 °C for at least 6 h, until the lubricant and coolant temperatures are within ±2 °C of the room temperature. If requested by the manufacturer, the test shall be carried out not later than 30 h after the vehicle has been run at its normal temperature.

B.5.3 Performance of the test

B.5.3.1 General

After preconditioning and conditioning in accordance with B.5.1 and B.5.2, respectively, one complete test cycle shall be run in accordance with B.4. The test equipment shall comply with B.2 and the test vehicle shall comply with B.3. The following requirements shall also be met during the test.

B.5.3.2 Additional conditions

The temperature shall be between 20 °C and 30 °C and the absolute humidity between 5,5 g and 12,2 g H_2O/kg dry air.

B.5.3.3 Performing the different steps of the test cycle

The test shall be performed in accordance with the prescriptions of the vehicle manufacturer, starting with the activation of the propulsion system and followed by applying the test cycle. To match the allowable tolerances of the test cycle, the procedure recommended by the vehicle manufacturer should be applied.

The hydrogen consumption shall be measured using one of the methods described in Clause 5 and Annexes D, E, and F, respectively. In the case of FCHEV, it shall be corrected, in accordance with 6.5, if necessary.

Annex C
(informative)

Test procedure in the U.S.A.

C.1 Background

Annex C describes the test procedure recommended for use in the USA and in other countries that use SAE (Society of Automotive Engineers, Inc.) methods for measuring fuel consumption and range of FCV and FCHEV fuelled by compressed gaseous hydrogen. Annex C makes reference to SAE J2572: 2006 as the specific governing document.

C.2 General

Annex C prescribes the uniform chassis dynamometer test procedures for FCV and FCHEV designed to be driven on public roads. Low-speed vehicles are not covered in Annex C. Instructions are given for measuring and calculating the fuel consumption and range using two test types:

— the “city” fuel consumption test using the Urban Dynamometer Driving Schedule (UDDS) and

— the “highway” fuel consumption test using the Highway Fuel Economy Driving Schedule (HFEDS).

Annex C covers only FCV fuelled with compressed gaseous hydrogen and FCHEV, also fuelled with compressed gaseous hydrogen, and which have a rechargeable energy storage system (RESS) (battery or capacitor).

C.3 General test information

C.3.1 Driving schedules

The driving schedules to be used for vehicle testing provided by the United States Environmental Protection Agency (EPA) are the Urban Dynamometer Driving Schedule (UDDS) and the Highway Fuel Economy Driving Schedule (HFEDS). The City Fuel Economy Test, which uses the UDDS, is detailed in SAE J2572: 2006, 6.1. The Highway Fuel Economy Test, which uses the HFEDS, is detailed in SAE J2572: 2006, 6.2.

C.3.2 Battery state of charge

If the net energy of the battery/capacitor system increases or decreases by less than or equal to 1 % of the total hydrogen energy consumed by the vehicle during the course of the test, the application of a correction equation is not necessary, i.e. no correction calculation is necessary if

$$\left| \frac{\Delta Stored\ electrical\ energy}{Total\ \ fuel\ energy\ consumed} \right| \leq 1\% \qquad \text{(C.1)}$$

where both the change in stored electrical energy (ΔE_{RESS}) and the total fuel (H_2) energy consumed, reported to one decimal point (e.g. 0,1 g), are expressed in units of energy (J). The lower net heating value for hydrogen gas is used to convert the total hydrogen consumed into units of Ah, using a factor of 120 000 J/g.

Expressed in terms of the energy content of hydrogen per unit of mass, the calculation is as follows:

$$|\Delta E_{RESS}| \leq 0{,}01 \times M \times 120\,000 \quad (C.2)$$

where

M is the total mass of hydrogen consumed over each phase of the test (M_{UDDS1}, M_{UDDS2}, M_{HWFET}), in g.

All mass values are reported to the nearest 0,1 g.

All distances are reported to the third decimal place (0,001 km).

All fuel consumption values are reported to the nearest 0,000 1 kg/km.

C.4 Test requirements

C.4.1 Vehicle condition

C.4.1.1 General

Prior to initiation of testing and during testing, the overall condition and configuration of the vehicle shall be as delineated in SAE J2572: 2006, 4.1 and subsequent subclauses, all of which are represented below.

C.4.1.2 Vehicle stabilization

Prior to testing, the test vehicle shall be stabilized as determined by the manufacturer to a minimum of 1 609 km (1 000 miles), but not more than 9 978 km (6 200 miles) using the durability driving schedule specified in CFR Title 40, Part 86, Appendix IV, section (a), or an equivalent schedule. For all preparations and testing, hydrogen complying with fuel specified by the SAE or the appropriate US government agency shall be used and that fuel shall comply with the fuel quality guidance specified in SAE J2719.

C.4.1.3 Vehicle appendages

Vehicles shall be tested with normal appendages (mirrors, bumpers, etc.). Certain items (e.g. hub caps) can be removed where necessary for safety on the dynamometer. If an off-board fuel source is used for the test, the test vehicle can include a connector to receive the fuel from that source.

C.4.1.4 Accessories

All accessories shall be turned off.

C.4.1.5 Vehicle test mass

The vehicle shall be tested at loaded vehicle weight (curb weight plus 136 kg [300 lb]).

C.4.1.6 Tyres

Manufacturer's recommended tyres shall be used. For dynamometer testing, tyre pressures should be set at the beginning of the test at the pressure used to establish the dynamometer road-load coefficients (see C.4.3) and shall not exceed levels necessary for safe operation. Tyres shall be conditioned as recommended by the vehicle manufacturer, have accumulated a minimum of 100 km (62 miles), and have at least 50 % of the original usable tread depth remaining.

C.4.1.7 Lubricants

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

C.4.1.8 Regenerative braking

If the vehicle has regenerative braking, the regenerative braking system shall be enabled for all chassis dynamometer testing, except for track coast down testing. If the regenerative braking level is adjustable, it shall be set in accordance with the manufacturer's specification prior to starting dynamometer testing. Operation of the regenerative braking system shall not cause speed and time tolerances specified by the test driving schedule to be exceeded.

C.4.1.9 Vehicle capability

The test vehicle shall be able to maintain the speed and distance tolerances required by the UDDS and HFEDS schedules.

C.4.1.10 Fuel cell stack condition

The stack shall have been aged with the vehicle as detailed in C.4.1.2, or equivalent conditioning.

C.4.1.11 Propulsion battery/capacitor condition

The propulsion system battery/capacitor shall have been aged with the vehicle, as detailed in C.4.1.2, or equivalent conditioning. The vehicle shall have an access point for measurement of current readings into and out of the energy storage device. Reading from a vehicle onboard current measurement system can be used provided that ±1 % NIST (National Institute of Standards and Technology) traceability can be demonstrated.

C.4.2 Environmental conditions

All test sequences shall be conducted with an ambient temperature within the range of 20 °C to 30 °C (68 °F to 86 °F).

C.4.3 Dynamometer

Use of an electric 48-inch single roll chassis dynamometer, or equivalent, is required for FCV and FCHEV testing. All factors concerning the dynamometer, specifically its capability requirements, configuration, calibration, warm-up, and settings, are presented in SAE J2572: 2006, 4.5 and subsequent subclauses, and these give further reference to other specific requirements as contained in CFR Title 40, Part 86, section 135-90 (i). The determination of the dynamometer load coefficients shall be as specified in SAE J2264.

C.4.4 Instrumentation

All instrumentation requirements for the test, including the list of instruments and instrument accuracy requirements, are presented in SAE J2572: 2006, 4.6 and subsequent subclauses. All instrumentation calibration must be NIST traceable to within ±1,0 % of the full scale of the appropriate range.

C.5 Required data collection

The data that must be collected regarding the vehicle, test conditions, instrumentation, fuel consumed and the dynamometer type, settings, and results are detailed in SAE J2572: 2006, 5.1, 5.2, and subsequent subclauses.

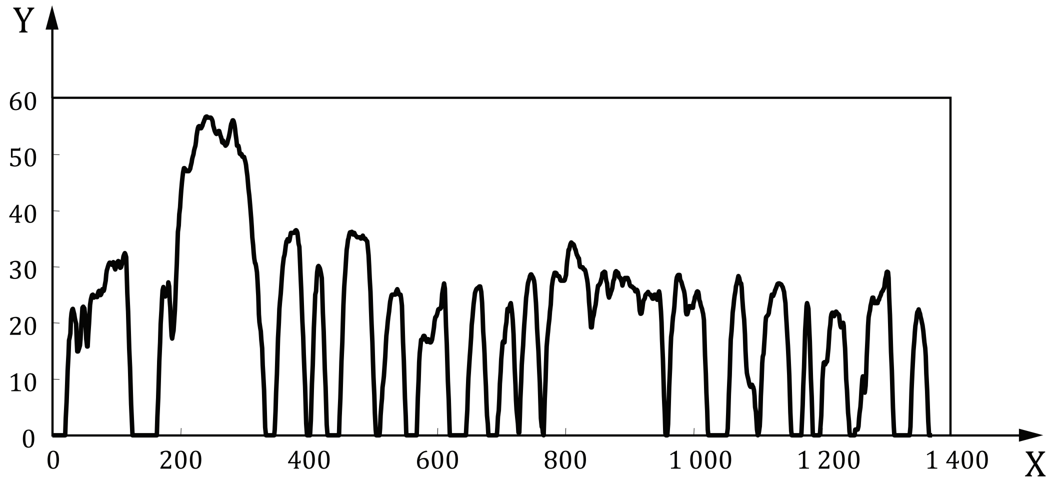
C.6 Testing the vehicle

C.6.1 General

The driving schedules provided by the U.S. Environmental Protection Agency (EPA) are used for the tests.

C.6.2 City fuel economy test

The driving cycle used for the city fuel economy test, illustrated in Figure C.1, represents US city driving and consists of a series of non-repetitive idle, acceleration, cruise, and deceleration modes of various time sequences throughout an interval of 1 372 s, as detailed in the EPA Urban Dynamometer Driving Schedule (UDDS). Full detail is provided in SAE J2572:2006, 6.1. Specific speed tolerance and fuel consumption considerations for the test sequence are presented in SAE J2572:2006, 6.3 and 6.4.



Key

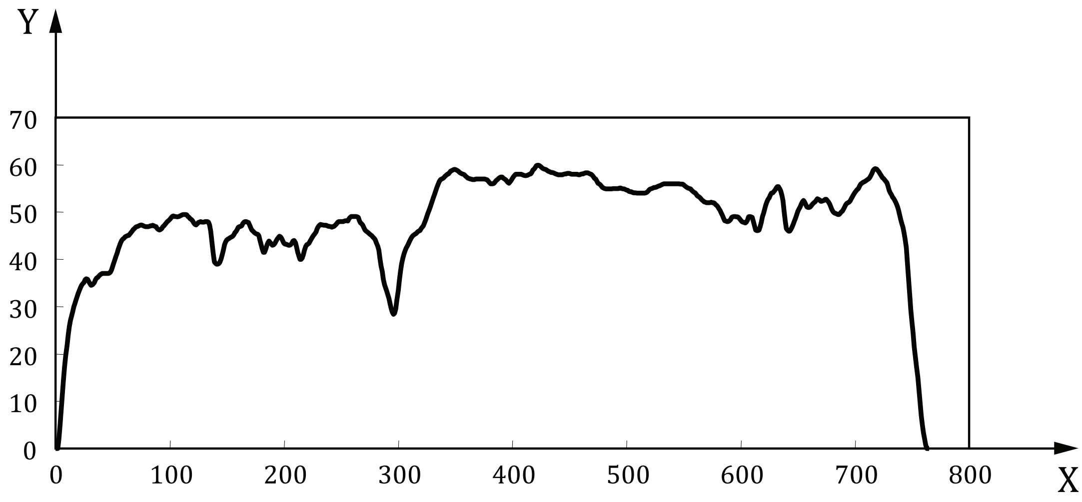
X time, s

Y vehicle speed, mph

Figure C.1 — Driving cycle used for the city fuel economy test

C.6.3 Highway fuel economy test

The driving cycle used for the highway fuel economy test, illustrated in Figure C.2, represents US highway driving and consists of a series of non-repetitive acceleration, cruise, and deceleration modes of various time sequences throughout an interval of 765 s, as detailed in the EPA Highway Fuel Economy Driving Schedule (HFEDS). Full detail is provided in SAE J2572: 2006, 6.2. Specific speed tolerance and fuel consumption considerations for the test sequence are presented in SAE J2572: 2006, 6.3 and 6.4.



Key

X time, s

Y vehicle speed, mph

Figure C.2 — Driving cycle used for the highway fuel economy test

C.7 Vehicle fuel consumption

C.7.1 Test method

Fuel consumed by a vehicle under test is determined by operating the vehicle on a dynamometer using prescribed driving cycles.

C.7.2 Measurement of fuel consumption

The fuel consumed is reported as the mass quantity of hydrogen consumed per distance travelled, specifically as kg/km. Three methods are available for determining the net change in mass of hydrogen during testing:

— the stabilized pressure and temperature for a fixed volume pressure vessel taken before and after each test,

— the gravimetric method for weighing auxiliary fuel tanks, and

— the use of an appropriate fuel flowmeter.

These three methods are presented in detail in SAE J2572: 2006, 7.2.1, 7.2.2, and 7.2.3, respectively.

C.7.3 Calculation of fuel consumption rate

Formulae 2 and 3 in SAE J2572: 2006, 7.3 are used to calculate fuel consumption, expressed in kg/km, for city driving and for highway driving, respectively.

C.7.4 Dynamometer coefficients

Dynamometer target coefficients are to be determined as prescribed in SAE J2264.

C.7.5 Dynamometer test procedure for city fuel consumption measurement

All specifics of the test procedure, including fuelling, temperature stabilization, vehicle preparation and preconditioning, dynamometer preparation, etc., as well as the details of the tests to be conducted, are presented in SAE J2572: 2006, 7.5.1 to 7.5.13.

C.7.6 Dynamometer test procedure for highway fuel economy measurement

All specifics of the test procedure, including fuelling, temperature stabilization, vehicle preparation, dynamometer preparation, etc., as well as the details of the tests to be conducted, are presented in SAE J2572: 2006, 7.6.1 to 7.6.13.

C.7.7 Fuel consumption calculation correction to account for battery/capacitor effect

For FCHEV, a method is provided to correct for the battery/capacitor influence on fuel consumption for the case where the final system state of charge has increased or decreased by more than 1 % from the initial system state of charge. For the case where there is an increase in battery/capacitor energy at the end of a test, the manufacturer has the option not to apply the correction calculation. Details of the calculation methods are presented in SAE J2572: 2006, 7.7 and subsequent subclauses, for a FCHEV equipped with a battery system, for the city (UDDS) test, and for the highway (HFEDS) test, as well as for the case of a hybrid vehicle equipped with a capacitor system.

C.8 Calculation of vehicle range

C.8.1 General

The driving range of a FCV and of a FCHEV is determined from the testing and calculation methods used to develop the fuel consumption information.

C.8.2 City range

City range, expressed in km, is determined by dividing the usable fuel amount (the difference in mass between the total fuel capacity and the unusable fuel amount) by the city fuel consumption (from SAE J2572: 2006, 7.3, Formula 2). [See CFR Title 40, Part 600, section 209-95 (a)(2)(i) regarding US labelling purposes.]

C.8.3 Highway range

Highway range, reported in kilometres, is determined by dividing the usable fuel amount by the corrected highway fuel consumption (from SAE J2572: 2006, 7.3, Formula 3). [See CFR Title 40, Part 600, section 209-95 (b)(2)(i) regarding US labelling purposes.]

C.8.4 Combined range

Combined range, reported in kilometres, is determined by dividing the usable fuel amount contained in the fuel tank by the combined fuel consumption. [See CFR Title 40, Part 600, section 209-95 (d)(2)(i).]

Annex D
(normative)

Pressure method

An example of instrumentation is shown in Figure D.1. An additional tank is used to measure the hydrogen consumption. The additional tank shall be connected to the vehicle.

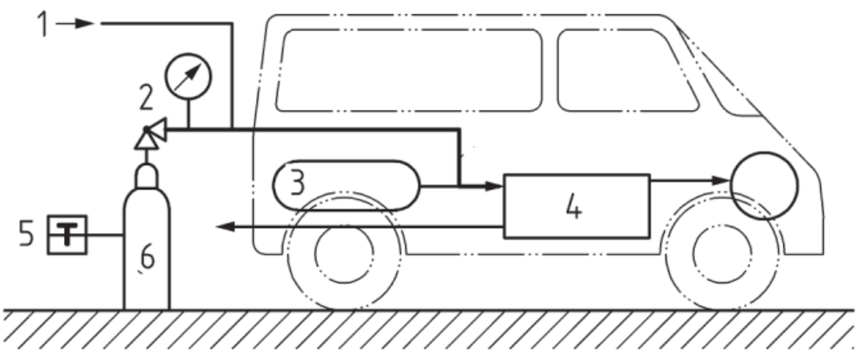
For preconditioning, the originally installed tank or an external source of hydrogen shall be used as shown in Figure D.1.

The refuelling pressure of the additional tank shall be adjusted according to the manufacturer's recommended values.

The following items are given as requirements for the additional tank. The internal volume of the tank and accessories (hydrogen lines, for example) upstream of the pressure regulator shall be known.

A means to measure the internal gas pressure and gas temperature shall be available. The volume change of the additional tank during the test shall be small enough not to affect the test result.

NOTE If gas temperature cannot be measured directly, an alternative method can be used, e.g. as described in Annex H.



Key

1 external hydrogen supply
2 pressure regulator
3 original tank
4 fuel cell system
5 temperature gauge
6 additional tank

Figure D.1 — Example of instrumentation

Table D.1 — Example of hydrogen tank for pressure method

Internal volume (measured)	**40,872 l**
Material	Cr-Mo steel
Refuelling gas	Pure hydrogen
Maximum refuelling pressure	14,7 MPa
Tank diameter (outside) × tank length	Ø 232 × 1170mm
Mass	about 42 kg

The measurement procedure is as described below.

a) At the start of the measuring run, the gas pressure and gas temperature of the tank shall be measured.

b) At the end of the measuring run, the gas pressure and gas temperature of the additional tank shall be measured.

c) Hydrogen consumption in mass, *w*, expressed in g, is calculated by the measured gas pressure and temperature before and after the test using the following formulae:

$$w = m \times (n_1 - n_2) \quad \text{(D.1)}$$

$$= m \times \frac{V}{R} \times \left(\frac{P_1}{z_1 \times T_1} - \frac{P_2}{z_2 \times T_2} \right) \quad \text{(D.2)}$$

where

w is the fuel consumption in mass (g);

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

n_1 is the molecular number of the gas in the tank at the start of measurement;

n_2 is the molecular number of the gas in the tank at the end of measurement;

V is the volume, in l, of the high-pressure section of the hydrogen tank and, if necessary, accessories (pressure regulators, hydrogen lines, for example);

R is the gas constant 0,008 314 5 (MPa·l / mol·K);

P_1 is the pressure, in MPa, of the gas in the tank at the start of measurement;

z_1 is the compression factor at P_1, T_1;

T_1 is the temperature, in K, of the gas in the tank at the start of measurement;

P_2 is the pressure, in MPa, of the gas in the tank at the end of measurement;

z_2 is the compression factor at P_2, T_2;

T_2 is the temperature, in K, of the gas in the tank at the end of measurement.

When a separate hydrogen supply line other than that for the hydrogen tank for the pressure method is also used, the gas supply pressures in both lines shall be maintained equal so that there is no input or output of gas when the lines are switched.

Annex E
(normative)

Gravimetric method

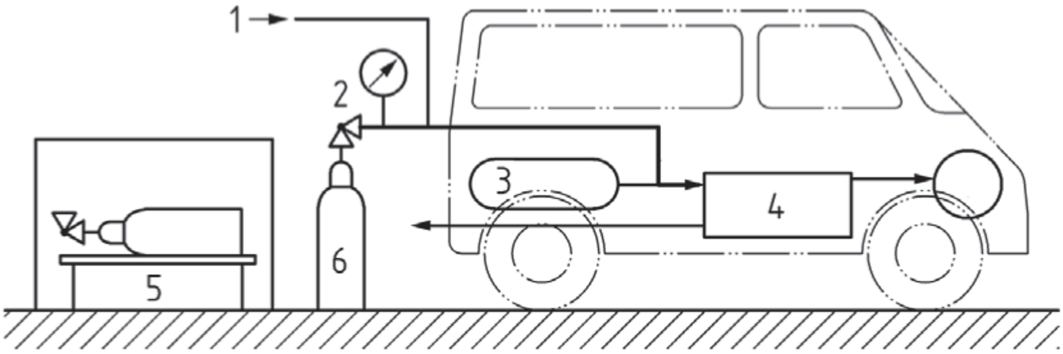
An example of instrumentation is shown in Figure E.1. An additional tank is used to measure the hydrogen consumption. The additional tank shall be connected to the vehicle.

For preconditioning, the originally installed tank or an external source of hydrogen shall be used as shown in Figure E.1.

The refuelling pressure shall be adjusted to the manufacturer's recommended value.

Since measurement of a small mass difference is necessary, it can be affected by vibration, convection, and ambient temperature. An appropriate means for reducing the effects of these factors, such as a damping table, wind barrier, etc., shall be provided.

The mass of the additional tank shall be minimized as much as possible because the mass of hydrogen to be measured is small in comparison to the mass of the tank.



Key

1 external hydrogen supply
2 pressure regulator
3 original tank
4 fuel cell system
5 precise balance
6 additional tank

Figure E.1 — Example of instrumentation

The test procedure is as described below.

a) Measure the mass of the additional tank before starting the ADT.

b) Connect the additional tank. The pressure of the connecting point shall be adjusted so that hydrogen consumed during the applicable driving test shall be supplied from the additional tank. It is necessary to prevent pressure difference between the fuel lines from influencing accuracy of the measurement.

c) Conduct the test by fuelling from the additional tank.

d) Remove the additional tank from the line and measure the mass after the test.

e) Calculate the hydrogen consumption in mass, w, expressed in g, from the measured mass before and after the test, using the following formula:

$$w = g_1 - g_2 \tag{E.1}$$

where

g_1 is the mass of the tank, in g, at the start of the test;

g_2 is the mass of tank, in g, at the end of the test.

Annex F
(normative)

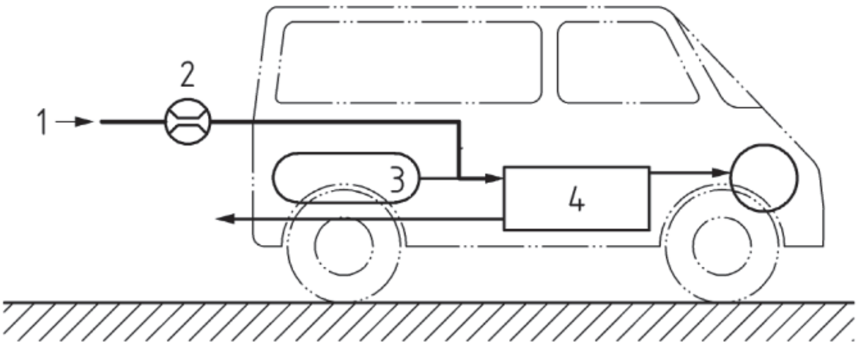
Flow method

An example of instrumentation is shown in Figure F.1.

A flowmeter shall be installed to measure the amount of hydrogen supplied to the fuel cell system during the test.

NOTE 1 It is recommended to calibrate the flowmeter with hydrogen. Improvement of accuracy is reported. See detail information in SAE 2007–01–2008.

NOTE 2 The accuracy of the flowmeter may be affected by pulsation in the fuel line in some cases. It is effective to install a device to decrease the pulsation between the flowmeter and vehicle fuel line. See the detailed information in SAE 2007–01–2008.



Key

1 external hydrogen supply

2 flowmeter

3 fuel tank

4 fuel cell system

Figure F.1 — Example of instrumentation

The hydrogen consumption in mass, *w*, expressed in g, shall be calculated by integrating the flow rate using the following formula:

$$b_{t0} = \int_0^t Q dt \quad (F.1)$$

$$w = b_{t0} \times \frac{m}{22{,}414} \tag{F.2}$$

where

b_{t0} is the fuel consumption in volume, in l at 273 K, 101,3 kPa;

Q is the measured hydrogen flow rate in test in l/s;

t is the measurement time;

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

Annex G
(informative)

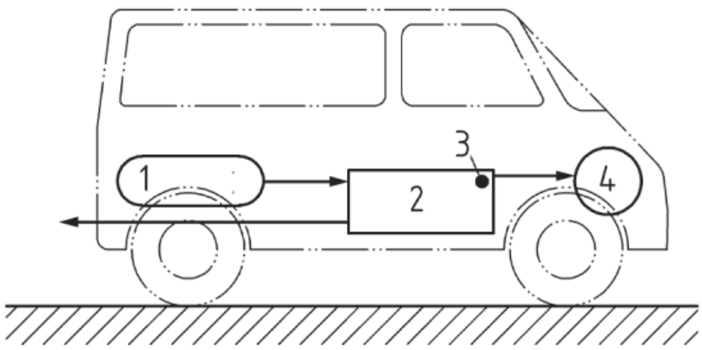
Current method

The electrical current method is designed to determine the quantity of hydrogen consumed, by measuring electrical current output from the fuel cell stack. Based on the principle that the amount of electrical current generation by a fuel cell stack is proportional to the quantity of hydrogen consumed, it is possible to determine hydrogen consumption by integrating electrical current values. However, the electrical current method cannot determine the quantity of the hydrogen that is not used in power generation, for example, hydrogen used for purging and lost through permeation. Therefore, if these losses are found to be significant, a different hydrogen consumption measurement method needs to be used.

An example of instrumentation is shown in Figure G.1. A current sensor shall be installed on the output wire of the fuel cell stack at a point near the fuel cell stack.

In the case of a clamp-type current sensor susceptible to the influence of a large current and magnetic field, care should be taken to avoid such influence and to ensure that there is no gap or foreign material in the clamp area when the sensor is installed, and any offset shall be compensated.

A current sensor shall be selected such that, in addition to its satisfactory measurement accuracy, its power input and sampling frequency can fully trace the current variations caused by the load variations of ADTs.



Key

1 fuel tank

2 fuel cell system

3 electric current sensor

4 electric drive

Figure G.1 — Example of instrumentation

From the integrated value of electrical current during the applicable driving test, the quantity of hydrogen consumption in volume, *bi*, expressed in l, (assuming 273 K and 101,3 kPa) is calculated according to the following formula:

$$b_i = \int_0^t I dt \frac{22{,}414}{v \times F} \times n \quad \text{(G.1)}$$

where

I is the current of the fuel cell stack, in A;

t is the measurement time;

v is the number of valence electrons (2 electrons);

F is the Faraday constant $9{,}648\,5 \times 10^4$, in C/mol;

n is the number of cells in the fuel cell stack.

Conversion from fuel consumption volume to mass is determined by applying the following formula.

$$w = b_i \times \frac{m}{22{,}414} \quad \text{(G.2)}$$

where

w is the fuel consumption in mass, in g;

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

Annex H
(informative)

Determination of tank surface temperature measuring points

H.1 General

Annex H describes a method of determining the tank surface temperature measuring points and tank soak time for pressure method.

H.2 Test conditions

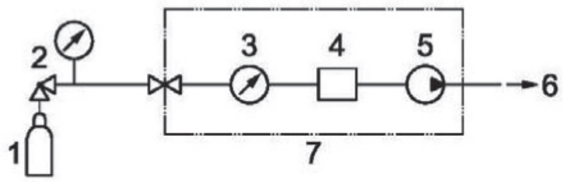
The ambient conditions such as the temperature and atmospheric pressure in the test room shall conform to the fuel consumption test conditions for FCV.

H.3 Test method

H.3.1 Test equipment

A standard flow rate generator shall be used that has the capability to generate a stable flow of hydrogen at a constant flow rate within ±1 % from a set value and that has a flow rate integration function (see Figure H.1).

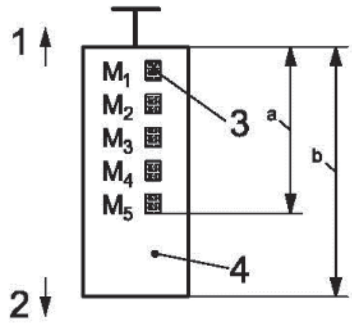
As shown in Figure H.2, the test tank shall be affixed with temperature sensors for measuring its external surface temperature. Sensors shall be affixed at points equidistant from one another and ranging over about two-thirds of the overall length (height) of the tank. Each sensor shall be covered with a heat insulating material for minimizing the influence of atmospheric temperature and shall be set in full contact with the tank surface.



Key

1 test tank
2 pressure regulator
3 pressure controller
4 sonic nozzle
5 suction pump
6 hydrogen
7 standard flow rate generator

Figure H.1 — Example of standard flow rate generator



Key

1 tank top

2 tank bottom

3 temperature sensor

4 test tank

$M_1...M_5$ temperature measurement points

[a] approximately 2/3 of overall tank length

[b] overall tank length

Figure H.2 — Temperature measuring points on the test tank

The test procedure is as described below.

a) Soak the test tank before the test until the internal gas temperature is stabilized to examine the effect of the measurement point of the tank surface temperature.

b) Activate the standard flow rate generator to discharge hydrogen from the tank at a constant flow rate. The flow rate, measuring time, and initial pressure of the hydrogen shall be set equivalent to those for the applied fuel consumption test.

c) Continue the measurements even after the end of discharge while the tank is being soaked.

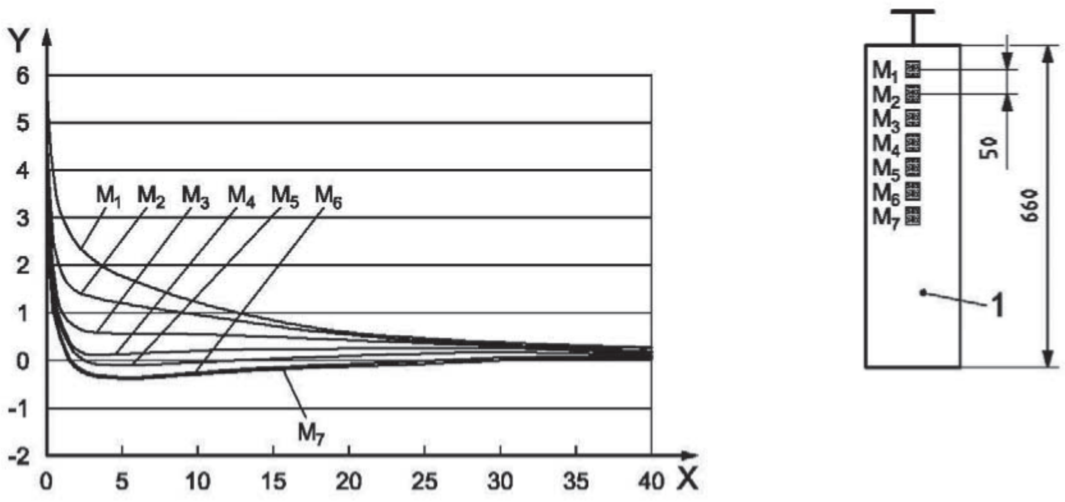
d) Calculate the quantity of discharged hydrogen, *w*, expressed in g, by applying the measured pressure and temperature to the following formula:

$$w = m \times \frac{V}{R} \times \left(\frac{P_1}{z_1 \times T_1} - \frac{P_2}{z_2 \times T_2} \right) \quad \text{(H.1)}$$

where

- m is the molecular mass of hydrogen (2,016);
- V is the volume, in l, of the high-pressure section of the hydrogen tank and, if necessary, accessories (pressure regulators, hydrogen lines, for example);
- R is the gas constant 0,008 314 5 (MPa·l / mol·K);
- P_1 is the pressure, in MPa, of the gas in the tank at the start of measurement;
- T_1 is the temperature, in K, of the gas in the tank at the start of measurement;
- P_2 is the pressure, in MPa, of the gas in the tank at the end of measurement;
- T_2 is the temperature, in K, of the gas in the tank at the end of measurement;
- z_1 is the compression factor at P_1, T_1;
- z_2 is the compression factor at P_2, T_2.

e) Determine the error of hydrogen quantity calculated in d) above by means of comparison with the integrated value of standard flow rates. Plot the error of each temperature measuring point against soak time, as illustrated in Figure H.3. Select the area (point) where the error converges on around 0 % for each line of every measurement point of the tank. The time corresponding to the selected area is determined as the soak time for each temperature measurement point.



a) b)

Key

X soak time (min)

Y error from integrated value of standard flow rates (%)

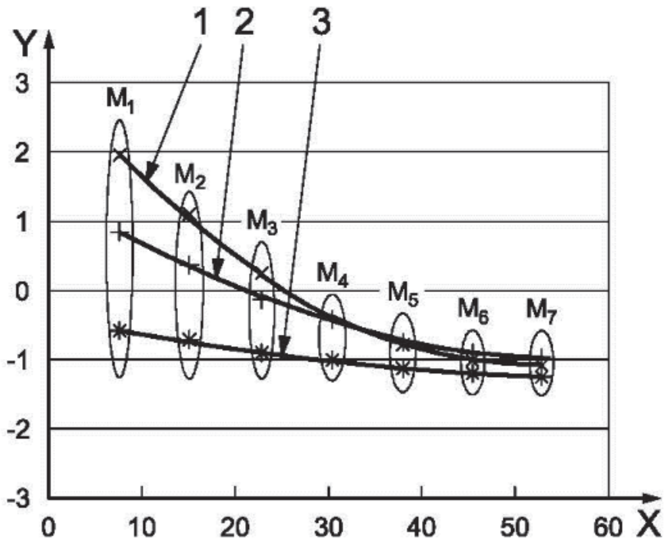
1 test tank

M_1...M_7 temperature measurement points

Figure H.3 — Example of error versus soak time/measurement points

f) In cases where the tank experiences a wide range of conditions such as flow rate, measuring time, and initial pressure of the hydrogen, repeat b) to e) under different conditions. Plot the data of pressure method errors against the temperature measuring points under the different test conditions. Derive the error distribution of the pressure method for each measuring temperature point. Set the points where the temperature sensors should be attached to target the error range of ±1 %. An example of the plot is shown in Figure H.4.

When an error is anticipated in measuring temperature due to a difference in the gas temperature before and after the test, the tank should be sufficiently soaked until the gas temperature in the tank becomes equal to the ambient temperature so that the hydrogen consumption can be determined from the pressure and temperature of gas after soak.



Key

X sensor position on tank (%)

Y error from integrated value of standard flow rates (%)

1 release quantity 500 l (normal), tank initial pressure 14 MPa

2 release quantity 500 l (normal), tank initial pressure 8 MPa

3 release quantity 500 l (normal), tank initial pressure 5 MPa

M_1...M_7 temperature measurement points

Figure H.4 — Example of error versus measurement points under wide range of initial tank pressure

Annex I
(informative)

Test results of hydrogen consumption of test vehicle

Date Test site Person responsible

Test vehicle:

Name and model:...

Chassis number:...

Total mileage:...km

Vehicle mass:...kg

Equivalent inertia mass (set value):...kg

Transmission:..

NOTE If the vehicle is modified to adjust to the dynamometer in accordance with 6.1.4, detail about the modification.

Tyre pressure of drive wheels:...kPa

RESS:

Rated capacity:...Wh Nominal voltage:....................................V

Instruments for hydrogen consumption measurement:

Hydrogen tank for pressure method: Internal volume in Annex D,...l

Hydrogen tank for gravimetric method (including accessories): mass... kg

Balance: Model:................., Minimum readability:...........g, Maximum measuring mass: .... kg

Flowmeter: Model:.., Type:..

Test results:

ADT:

Start-up time: .... h .... min

Relative humidity in test room:..%

Atmospheric pressure in test room:.................................hPa

Driven distance:.. km

Pressure method	Tank pressure, temperature
	(Before test)..MPa, ... °C
	(After test) ....MPa, ... °C
Gravimetric method	Mass of the tank (Before test)...............g, (After test)....................g
Flow method	Flow volume supplied to vehicle ....l at 273K, 101,3 kPa

Measured hydrogen amount: .... g

ΔE_{RESS}:... Wh

NOTE If the measured result is corrected in accordance with 6.5, calculate the hydrogen consumption as described in Annex K.

Hydrogen consumption: ....g Hydrogen consumption (per unit volume): ....km/l(Normal)

Hydrogen consumption (per unit mass): ....km/kg

Hydrogen consumption (per unit calorie): ....km/MJ

Remarks:

Annex J
(normative)

Calculation of allowable range of RESS energy change

J.1 General

The allowable energy change in the RESS calculated by Formula (4) may be rewritten as follows using the net heating value (NHV) of fuel.

$$\left|\Delta E_{RESS}\right| \leq 0{,}01 \times J_{NHV} \times m_{fuel} \times 3600 \quad \text{(J.1)}$$

where

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

J_{NHV} is the net heating value (per consumable fuel analysis), in J/kg;

m_{fuel} is the total mass of fuel consumed over the ADT, in kg.

For batteries or capacitors, this allowable energy change can be expressed as shown in J.2 and J.3.

J.2 Batteries

The energy balance in a battery over the ADT, ΔE_b, in Wh, can be calculated from the measured charge balance, ΔQ, and expressed as follows:

$$\Delta E_b = \Delta Q \times V_b \quad \text{(J.2)}$$

where

ΔQ is the charge balance of the battery over ADT, in Ah;

V_b is the nominal voltage of battery system, in V.

NOTE V_b means the same as nominal voltage in ISO 12405-1 or ISO 12405-2.

For a battery, Formula (J.2) may be rewritten as follows:

$$\left| \Delta Q \right| \leq 0{,}01 \times \frac{J_{NHV} \times m_{fuel}}{V_b} \times 3600 \quad \text{(J.3)}$$

J.3 Capacitors

The change of energy stored in a capacitor over ADT, ΔE_c, in Wh, is expressed as follows:

$$\Delta E_c = \frac{C}{2} \times \left(V_{final}{}^2 - V_{initial}{}^2 \right) \times 3600 \qquad (J.4)$$

where

C	is the nominal capacitance of capacitor, in F;
V_{final}	is the terminal voltage of capacitor at the end of the test, in V;
$V_{initial}$	is the terminal voltage of capacitor at the start of the test, in V.

For a capacitor, Formula (J.4) may be rewritten as follows:

$$\left| V_{final}{}^2 - V_{initial}{}^2 \right| \leq 0{,}01 \times \frac{2 \times J_{NHV} \times m_{fuel}}{C} \qquad (J.5)$$

Annex K
(normative)

Linear correction method using a correction coefficient

K.1 General

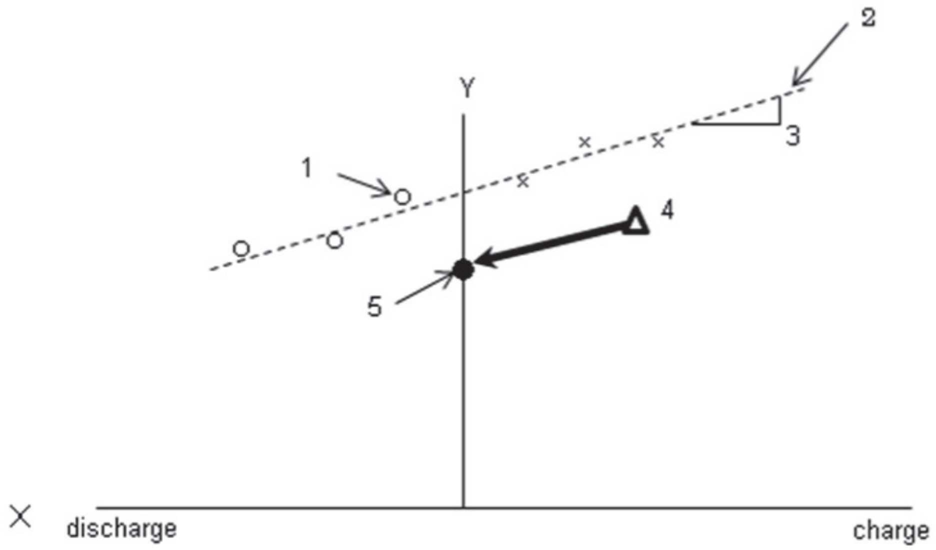
Annex K describes the calculation procedure to determine the fuel consumption at $\Delta E_{RESS} = 0$.

K.2 Method for correcting the fuel consumption

K.2.1 Data required for correction coefficient

The hydrogen consumption test shall be repeated several times to determine the correction coefficient defined in K.2.1.1.1 (see Figure K.1). The ΔE_{RESS} shall be measured during the test. The SOC and ΔE_{RESS} should be in the normal range specified by the vehicle manufacturer.

NOTE The charge balance may be used instead of energy balance in case of batteries.



Key

X energy balance (Wh)

Y consumed fuel (M_E)

1 ○ × data (C_i, M_{Ei})

2 pre-measured line for determination of correction coefficient

3 K_{ME}

4 Δ measured value (C_s, M_{Es})

5 · corrected value (M_{Ec}) = $M_{Es} - K_{ME} \times C_s$

Figure K.1 — Example data collected from ADT

K.2.2 Corrections

K.2.2.1 Correction coefficient, K_{ME}

The hydrogen consumption correction coefficient, K_{ME}, in g (Wh), shall be calculated using the following formula:

$$K_{ME} = \frac{n \times \sum C_i M_{E\,i} - \sum C_i \times \sum M_{E\,i}}{n \times \sum C_i^{\,2} - (\sum C_i)^2} \quad \text{(K.1)}$$

where

$M_{E\,i}$	is the hydrogen consumption of the test, in g;
C_i	is the energy balance at the hydrogen consumption test, in Wh (use the minimum unit);
n	is the number of data.

K.2.2.2 Hydrogen consumption at ($\Delta E_{RESS} = 0$), M_{EC}

The amount of hydrogen consumption at ($\Delta E_{RESS} = 0$), M_{EC}, expressed in g, is derived from the following formula:

$$M_{EC} = M_{Es} - K_{ME} \times C_S \quad \text{(K.2)}$$

where

M_{Es}	is the hydrogen consumption, in g;
C_s	is the energy balance of battery, in Wh, (use the minimum unit).

Bibliography

[1] ISO 12405-1, *Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems — Part 1: High-power applications*

[2] ISO 12405-2, *Electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems — Part 2: High-energy applications*

[3] *Announcement that Prescribes Details of Safety Regulations for Road Vehicles (Ministry of Land, Infrastructure, Transport and Tourism [MLIT] Announcement No. 619, 2002;) Attachment 42*

[4] TRIAS 99-006 *(TRIAS is available for purchase at JASIC HP [*http://www.jasic.org/e/08_publication/bb/20_handbook.htm*])*

[5] TRIAS 31-J042(3)

[6] Regulation No UNECE 83, *Uniform provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements*

[7] Regulation No UNECE 101, *Uniform provisions concerning the approval of passenger cars powered by an internal combustion engine only, or powered by a hybrid electric power train with regard to the measurement of the emission of carbon dioxide and fuel consumption and/or the measurement of electric energy consumption and electric range, and of categories M1 and N1 vehicles powered by an electric power train only with regard to the measurement of electric energy consumption and electric range*

[8] SAE J2263, *Road Load Measurement Using Onboard Anemometry and Coastdown Techniques*

[9] SAE J2264, *Chassis Dynamometer Simulation of Road Load Using Coastdown Techniques*

[10] SAE J2572, *Recommended Practice for Measuring the Fuel Consumption and Range of Fuel Cell and Hybrid Fuel Cell Vehicles Fuelled by Compressed Gaseous Hydrogen*

[11] SAE J2719, *Hydrogen Fuel Quality for Fuel Cell Vehicles*

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