



Technical Report

ISO/TR 11954

Fuel cell road vehicles — Performance measurement — Vehicles fuelled with compressed hydrogen

Véhicules routiers avec pile à combustible — Mesure des performances — Véhicules alimentés par hydrogène comprimé

**Second edition
2024-01**

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 document 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 second edition cancels and replaces the first edition (ISO/TR 11954:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

- revision of the scope;
- addition of normative references;
- addition of terms and definitions, e.g. complete vehicle kerb mass, maximum thirty minutes speed, acceleration, speed uphill and hill starting performance;
- addition of driving performance tests, e.g. maximum thirty minutes speed, acceleration, speed uphill and hill starting performance;
- revision of the method for adjusting the RESS SOC;
- addition of driving mode setting method.

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 — Performance measurement — Vehicles fuelled with compressed hydrogen

1 Scope

This document specifies test methods for the measurement of performance, such as acceleration, maximum speed and hill climbing ability, of fuel cell hybrid electric vehicles (FCHEV) as passenger cars and light duty trucks with a maximum authorized total mass of 3 500 kg and fuelled with 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/TR 8713:2019, *Electrically propelled road vehicles — Vocabulary*

3 Terms and definitions

For the purposes of this document, the following 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 acceleration ability

shortest time required to accelerate the vehicle from speed v_1 to speed v_2

[SOURCE: ISO 8715:2001, 3.7, modified — Note 1 to entry was removed.]

3.2 complete vehicle kerb mass

mass of the vehicle including batteries, without occupants but with fuel, cooling liquid, window washer fluid, lubricating oil, tools and spare wheel, on-board charger, portable charger or part of it, if provided as standard equipment by the vehicle manufacturer

[SOURCE: ISO 8715:2001, 3.1]

3.3 dynamic loaded radius

effective radius of a tyre when it is deformed by the mass of the vehicle loaded to its *test mass* (3.14)

[SOURCE: ISO 8715:2001, 3.4]

3.4 FCHEV operation mode fuel cell hybrid electric vehicle operation mode

mode of a *fuel cell hybrid electric vehicle (FCHEV)* (3.5) in which both a *rechargeable energy storage system (RESS)* (3.10) and fuel cell system are used sequentially or simultaneously for vehicle propulsion

3.5

FCHEV

fuel cell hybrid electric vehicle

electrically propelled vehicle with a *rechargeable energy storage system (RESS)* (3.10) and a fuel cell system as power sources for vehicle propulsion

[SOURCE: ISO 23828:2022, 3.7]

3.6

hill starting ability

maximum slope on which the vehicle can start moving over a minimum distance of 10 m

[SOURCE: ISO 8715:2001, 3.9]

3.7

maximum design total mass

maximum vehicle mass as specified by the vehicle manufacturer

[SOURCE: ISO 8715:2001, 3.2]

3.8

maximum speed

highest average speed which the vehicle can maintain throughout a specified test

[SOURCE: ISO/TR 8713:2019, 3.89]

3.9

maximum thirty minutes speed

v_{30}
highest average speed which the vehicle can maintain over 30 min

[SOURCE: ISO 8715:2001, 3.6, modified — Note 1 to entry was removed.]

3.10

RESS

rechargeable energy storage system

rechargeable system that stores energy for delivery of electric energy for the electric drive

EXAMPLE Battery, capacitor, flywheel.

[SOURCE: ISO/TR 8713:2019, 3.117]

3.11

RESS SOC

RESS state of charge

residual capacity of a *rechargeable energy storage system (RESS)* (3.10) available to be discharged

3.12

RESS operation mode

rechargeable energy storage system operation mode

mode of an *fuel cell hybrid electric vehicle (FCHEV)* (3.5) using only a *rechargeable energy storage system (RESS)* (3.10) for vehicle propulsion

3.13

speed uphill

highest average speed which the vehicle can maintain on a given slope over a distance of 1 km

[SOURCE: ISO 8715:2001, 3.8]

3.14

test mass

sum of the *complete vehicle kerb mass* (3.2) plus

- the maximum authorized load mass (including driver) if it is equal or less than 180 kg;
- 180 kg, if the maximum authorized load mass exceeds 180 kg but is less than or equal to 360 kg;
- half of the maximum authorized load mass if this load mass exceeds 360 kg

[SOURCE: ISO 8715:2001, 3.3]

4 Parameters, units and accuracy of measurements

Table 1 shows parameters and their units and accuracy.

Table 1 — Parameters, units and accuracy of measurements

Parameter	Unit	Accuracy
Time	s	±0,1 s
Distance	m	±0,1 %
Air temperature	°C	±1 °C
Air pressure	kPa	±1 kPa
Speed	km/h	±1 % or ±0,1 km/h whichever is greater
Mass	kg	±0,5 %
Tyre pressure	kPa	±1,5 %
DC current	A	±0,3 % ^a

^a For the DC current measurement, a wideband current meter or wideband ampere-hour meter for operation in connection with pulsed power electronics is used. Any errors in the DC electric energy measurement system are less than 1 % of the reading or 0,3 % of full scale.

5 Test conditions

5.1 Vehicle conditions

The vehicle is loaded to the test mass according to the specification given for each test.

The vehicle tyres are inflated to the pressure specified by the vehicle manufacturer when the tyres are at ambient temperature.

The viscosity of oils for the mechanical moving parts conforms to the specification of the vehicle manufacturer.

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

All energy storage systems available for other than traction purposes (electric, hydraulic, pneumatic, etc.) are charged up to their maximum level specified by the vehicle manufacturer.

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

If batteries are to be operated at temperatures above ambient temperature, the driver follows the procedure recommended by the vehicle manufacturer to keep the battery temperature within its operating range.

The vehicle is driven over at least 300 km before the test(s) with the onboard fuel cell system.

The RESS is in the state of charge required for the test to be performed.

The hydrogen fuel tank is filled according to the test to be performed with a fuel quality according to ISO 14687 and the equivalent regional standard.

5.2 Atmospheric conditions

5.2.1 Ambient temperature and atmospheric pressure

The outdoor test is performed at an ambient temperature between 5 °C and 32 °C. Indoor tests are performed at a room temperature between 20 °C and 30 °C. The atmospheric pressure is between 91 kPa and 104 kPa. The tests are performed in the absence of rain and fog.

5.2.2 Air density

According to [Formula \(1\)](#), the air density in the test does not change more than 7,5 % compared with the air density in the reference conditions.

Air density calculation is obtained according to [Formula \(1\)](#):

$$d_r = d_0 \times \frac{H_T}{H_0} \times \frac{T_0}{T_T} \quad (1)$$

where

d_0 is the air density in reference conditions [$d_0 = 1,189 \text{ kg/m}^3$];

H_T is the pressure during the test;

H_0 is the pressure at reference conditions [$H_0 = 100 \text{ kPa}$];

T_T is the absolute temperature during the test, in kelvins;

T_0 is the temperature at reference conditions [$T_0 = 293 \text{ K (20 °C)}$].

5.2.3 Wind speed

The average wind speed measured at a height of 1 m above the ground is less than 3 m/s. Gusts are less than 5 m/s.

5.2.4 Relative humidity

The relative humidity is less than 95 % and the track is dry.

5.3 Track conditions

5.3.1 General conditions

The measurements are taken on a dry track, which can be either a straight track or a loop track. The surface of the track is hard, smooth, clean and give good adhesion.

5.3.2 Straight track

The length of the measuring zone is at least 1 000 m.

The length of the launching track is long enough to achieve a stable speed 200 m ahead of the measuring zone. The longitudinal slope on the measuring zone and on the last 200 m of the launching track does not exceed 0,5 %. The longitudinal slope on the launching tracks does not exceed 4 %.

The transverse slope in the measuring zone does not exceed 3 %.

In order to reduce the influence of factors such as road slope and wind direction/speed, the acceleration and the speed tests are executed in both directions of the test track in direct sequence, taking care to use the same stretch of the track.

When conditions preclude performing the test in both directions, a single direction test is carried out as in [5.3.4](#).

5.3.3 Loop track

The length of the loop track is not less than 1 000 m. For calculating the speeds, the length of run is the distance covered by the vehicle while it is being timed.

The loop track may vary from a perfect circle to straight sections linked by approximately circular sections. The radius of the curves is not less than 200 m.

The longitudinal slope in the measuring zone does not exceed 0,5 %. The effects of centrifugal forces can be compensated by the transverse profile of the curves in such a way that the vehicle holds a normal line without any action on the steering wheel.

5.3.4 Single direction test

Testing in one direction only is permitted on the straight track if, because of the characteristics of the test track layout, it is not possible for the vehicle to reach its maximum speed in both directions.

The following conditions are fulfilled:

- the track conforms to the information provided in [5.3.2](#);
- the variation in altitude does not exceed 1 m between any two points;
- the run is repeated twice in immediate succession;
- the components of wind speed parallel to the track does not exceed 2 m/s.

6 Preconditioning of the vehicle

6.1 Hydrogen refuelling

Hydrogen is refuelled to the vehicle's hydrogen tank according to the vehicle manufacturer's specification. The hydrogen refuelling procedures complies with the relevant hydrogen refuelling standards.

6.2 RESS state of charge preconditioning of externally chargeable FCHEV

Vehicle performance of externally chargeable FCHEV is evaluated under FCHEV operation mode. To avoid the test in RESS operation mode, initial SOC of RESS on performance test is limited in certain level. Before the performance test, SOC of RESS is confirmed in the allowable SOC range. This allowable SOC range can be reached by the following steps.

- a) The initial SOC of RESS is set according to the manufacturer's instructions, so that the vehicle system reaches the FCHEV operation mode during the 30 min maximum speed test. If the manufacturer's instructions are not available, initial SOC range could be between 30 % to 70 %.
- b) The 30 min maximum speed test is performed. And the profile of the SOC during the test is recorded.
- c) The minimum SOC value ($S_{OC, V30_min}(\%)$) is obtained during the test. ($S_{OC, V30_min}$ is the minimum SOC level after FC system works during the performance test.) Then, the allowable SOC range of RESS to start performance test is within $S_{OC, V30_min} \pm 10 \%$.

If SOC information is not available or feasible at some special situation, quantity of electricity measurement of the RESS ($Q_{RESS}(\text{Ah})$) can be applied instead of SOC(%). Details of the procedure are listed in [Annex B](#). The procedure in [B.1](#) uses full charge operation to initiate the quantity of electricity value by referring the nominal capacity ($Q_{NOMINAL}$) and also uses discharge operation to adjust SOC to the initial SOC ($S_{OC, INI}$) before the 30 min maximum speed test. For FCHEV with large RESS, the procedure in [B.2](#) can be used to set $S_{OC, INI}$ to avoid drawbacks of the associated power loss and time required.

6.3 Warming up

The vehicle is driven over a distance of about 5 000 m at 80 % of the manufacturer's estimated maximum thirty minutes speed in order to warm up the motor and transmission gears.

6.4 Selection of driving mode

If the vehicle has multiple driving modes (e.g. intelligent mode, sports mode), and if the vehicle has a main or default mode, it is operated in main or default mode. If the vehicle has no main or default mode, the driving mode recommended by the vehicle manufacturer is selected and noted in the record of [Annex A](#).

7 Test sequence

7.1 Test sequence for non-externally chargeable FCHEV

Test for non-externally chargeable FCHEV is performed by following steps.

- a) The vehicle is loaded to the test mass (see [3.14](#)).
- b) Vehicle is preconditioned without SOC preconditioning (see [6.1](#)).
- c) The warming up operation is performed (see [6.3](#)).
- d) The driving mode is selected (see [6.4](#)).
- e) The FCHEV operation mode test items number 1 to 4 in [Table 2](#) are performed sequentially.
- f) The vehicle is loaded to its maximum design total mass.
- g) The FCHEV operation mode test items number 5 and 6 in [Table 2](#) are performed sequentially.

7.2 Test sequence for externally chargeable FCHEV

Test for externally chargeable FCHEV is performed by following steps.

- a) The vehicle is loaded to the test mass (see [3.14](#)).
- b) Vehicle is preconditioned with SOC preconditioning (see [6.1](#), [6.2](#)).
- c) The warming up operation is performed. (It can be skipped if test is performed in a short pause.)
- d) The driving mode is selected (see [6.4](#)).
- e) The FCHEV operation mode test items number 1 to 4 in [Table 2](#) are performed sequentially. Each test starts within the allowable SOC range of RESS described in [6.2](#), [B.1](#) or [B.2](#).
- f) The vehicle is loaded to its maximum design total mass.
- g) The FCHEV operation mode test items number 5 and 6 in [Table 2](#) are performed sequentially. Each test starts within the allowable SOC range of RESS described in [6.2](#), [B.1](#) or [B.2](#).

According to the manufacturer's requirements, the maximum speed and acceleration ability test according test item number 7 to 8 of [Table 2](#) in the mode recommended by the manufacturer can be added. Therefore, the RESS SOC of the vehicle can be adjusted according to the manufacturer's requirements.

Table 2 — Test procedure

NO.	Reference	Items	Note
1	6	Preconditioning	
2	8.1	Maximum speed in FCHEV operation mode	Mandatory
3	8.2	Maximum thirty minutes speed in FCHEV operation mode	Mandatory
4	8.3	Acceleration ability in FCHEV operation mode	Mandatory
5	8.4	Speed uphill in FCHEV operation mode	Mandatory
6	8.5	Hill starting ability in FCHEV operation mode	Mandatory
7	8.1	Maximum speed in the mode recommended by the manufacturer	Optional
8	8.3	Acceleration ability in the mode recommended by the manufacturer	Optional
9	ISO 8715	Maximum speed in RESS operation mode	Optional
10	ISO 8715	Acceleration ability in RESS operation mode	Optional
11	ISO 8715	Speed uphill in RESS operation mode	Optional
12	ISO 8715	Hill starting ability in RESS operation mode	Optional

8 Test procedure

8.1 Maximum speed

8.1.1 Standard test procedure

The test procedure is as follows.

- The vehicle is brought to a maximum speed on the straight or loop track and it is maintained at this speed over a distance of 1 km.
- The same test is performed immediately in the opposite track direction.

The maximum speed value in kilometres per hour (km/h) is the arithmetic average between the two measured values.

8.1.2 Single direction test procedure

The test procedure is as follows.

- The vehicle is brought to a maximum speed and it is maintained at this speed over a distance of 1 km.
- The single direction test is carried out using a test track as in [5.3.4](#). The speed results for the two runs, $v_{\text{mes}_r_n}$, the maximum speed per run corrected by the wind speed, $v_{\text{max}_r_n}$, and the maximum speed v_{max} is determined according to [Formulae \(2\)](#) to [\(4\)](#):

$$v_{\text{mes}_r_n} = L_n / t_n \quad (2)$$

$$v_{\text{max}_r_n} = (v_{\text{mes}_r_n} \pm v_w \times f) \times 3,6 \quad (3)$$

$$v_{\text{max}} = (v_{\text{max}_r_1} + v_{\text{max}_r_2}) / 2 \quad (4)$$

where

- $v_{\text{mes}_r_n}$ is the measured speed for test run n in m/s;
- n is the counter for test run 1 or 2;
- L_n is the measured length for test run n at maximum speed in m;
- t_n is the measured time for test run n in s;
- $v_{\text{max}_r_n}$ is the determined maximum speed for test run n in km/h;
- \pm the + sign is used if the axial wind component is in the opposite direction to the vehicle driving direction; the – sign is used if the axial wind component is in the same direction as the driving direction;
- v_{vw} is the axial wind component in m/s;
- f is the wind correction factor = 0,6;
- v_{max} is the maximum speed determined as arithmetic average for the two test runs in km/h.

8.2 Maximum thirty minutes speed

The test of the maximum thirty minutes speed is performed either on a loop track or on a chassis dynamometer calibrated according to ISO 8715, as follows.

- a) The maximum thirty minutes speed, v_{30} , is determined by driving the vehicle at the manufacturer's best estimate of such a speed $\pm 5\%$ for 30 min. (Speed variations during the test can be compensated for by pressing the accelerator pedal to match the $\pm 5\%$ range.)
- b) The distance covered, d , is measured, in metres, and the average thirty minutes speed, v_{30} , is calculated, in kilometres per hour (km/h) with the [Formula \(5\)](#):

$$v_{30} = d / 500 \quad (5)$$

- c) If the speed has dropped below the – 5 % level during the test, the test can be repeated at the manufacturer's discretion with either the same or a revised manufacturer's estimated maximum thirty minutes speed.

8.3 Acceleration ability (v_1 to v_2)

8.3.1 Acceleration ability 0 km/h to 50 km/h

The test procedure is as follows.

- a) The vehicle is stopped on the test track in the start position.
- b) The vehicle is accelerated by fully activating the accelerator pedal and, if fitted, by using the clutch and gear lever.
- c) The time is recorded which elapsed from depressing the accelerator pedal to achieving the speed of (50 ± 1) km/h.
- d) The same test in the opposite direction is performed immediately.

The 0 km/h to 50 km/h acceleration in seconds [s] is the arithmetical average of the two measured time periods.

8.3.2 Acceleration ability 50 km/h to 80 km/h

The test procedure is as follows.

- a) The vehicle is stopped on the test track in the start position.
- b) The vehicle is accelerated to the speed of (50 ± 1) km/h, and it is maintained at this speed over 0,5 km.
- c) The vehicle is accelerated by fully depressing the accelerator pedal and, if fitted, by using the clutch and gear lever.
- d) The time is recorded which elapsed from fully depressing the accelerator pedal to achieving the speed of (80 ± 1) km/h or 90 % of the maximum speed, if it is lower than 89 km/h. In this case the final speed is noted in the report.
- e) The same test in the opposite direction is performed immediately.

The 50 km/h to 80 km/h acceleration in seconds (s) is the arithmetical average of the two measured time periods.

8.4 Speed uphill

The test procedure is as follows.

- a) The vehicle is positioned on the dynamometer and adjustments could be made to suit the ISO-M07 mass value.

NOTE The test can also be done using a dynamometer trailer.

- b) The bench is set up with an additional load corresponding to a 4 % slope.
- c) The vehicle is accelerated by fully depressing the accelerator pedal.
- d) The maximum stabilized speed value that the vehicle can reach and travel over a distance of 1 km is determined.
- e) The test starting with the bench set up with an additional load corresponding to a 12 % slope is repeated.

8.5 Hill starting ability

8.5.1 Principle

The measurement of hill starting ability is performed by starting on a slope featuring an angle, α_1 , as near as possible to the vehicle manufacturer's claimed hill starting ability, α_0 .

The difference between the real angle α_1 and the claimed α_0 is compensated for by an additional or a reduced mass Δm .

In the case where the angle α_0 is unknown, it can be evaluated using [Formulae \(7\)](#) and [\(8\)](#).

8.5.2 Procedure

The test procedure is as follows.

- a) The vehicle is arranged on test gradient slope α_1 which is selected as near as possible to α_0 , and faces up the slope.
- b) The mass Δm is added or reduced, which is calculated with [Formula \(6\)](#):

$$\Delta m = m \frac{(\sin \alpha_0 - \sin \alpha_1)}{(\sin \alpha_1 - R)} \quad (6)$$

where

m is the mass ISO-M07 of the vehicle under test, in kg;

R is the tyre rolling resistance, conventionally equal to 0,005 to 0,01.

The mass Δm is uniformly distributed in passenger and load compartments.

c) The vehicle runs over a distance of at least 10 m.

8.5.3 Evaluation of α_0

With known peak motor shaft torque, the wheel torque is calculated with [Formula \(7\)](#):

$$C_r = C_a \times T \times \eta_\tau \quad (7)$$

and with known tyre rolling radius the balance of forces:

$$F_t = \frac{C_r}{r} = m \times g \times (\sin \alpha_0 + R) \quad (8)$$

where

C_r is the wheel torque;

C_a is the maximum peak motor shaft torque;

T is the total gear ratio;

η_τ is the gear efficiency;

F_t is the total traction force necessary to balance the load, in Nm;

r is the tyre dynamic loaded radius, in m;

g is the acceleration of gravity, in m/s².

From [Formulae \(7\)](#) and [\(8\)](#), α_0 and the hill starting ability, equals to

$$\tan \alpha_0 \times 100 \quad (9)$$

can be calculated.

Annex A
(informative)

Test results of performance measurements

Date: Test site: Person responsible: Temperature:

Test vehicle:

1. Name and model:.....
2. Chassis number:.....
3. Total mileage:..... km
4. Complete vehicle kerb mass:..... kg
5. Test mass:..... kg
6. Transmission:.....
7. Tyre pressure of drive wheels:..... kPa
8. Dynamic loaded radius (tyre):..... m
9. Driving mode:.....

RESS:

1. Rated capacity:..... kWh Nominal voltage:..... V

Fuel cell:

1. Nominal power:..... kW

Test results:

Maximum speed in mode: km/h

Maximum thirty minutes speed in mode: km/h

Acceleration time in..... mode:

..... km/h to km/h:..... s

..... km/h to km/h:..... s

Speed uphill:

on a 4 % slope: km/h

on a 12 % slope: km/h

Hill starting ability:

Remarks:

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